State of California

THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 74-5

WATER WELL STANDARDS: SAN JOAQUIN COUNTY

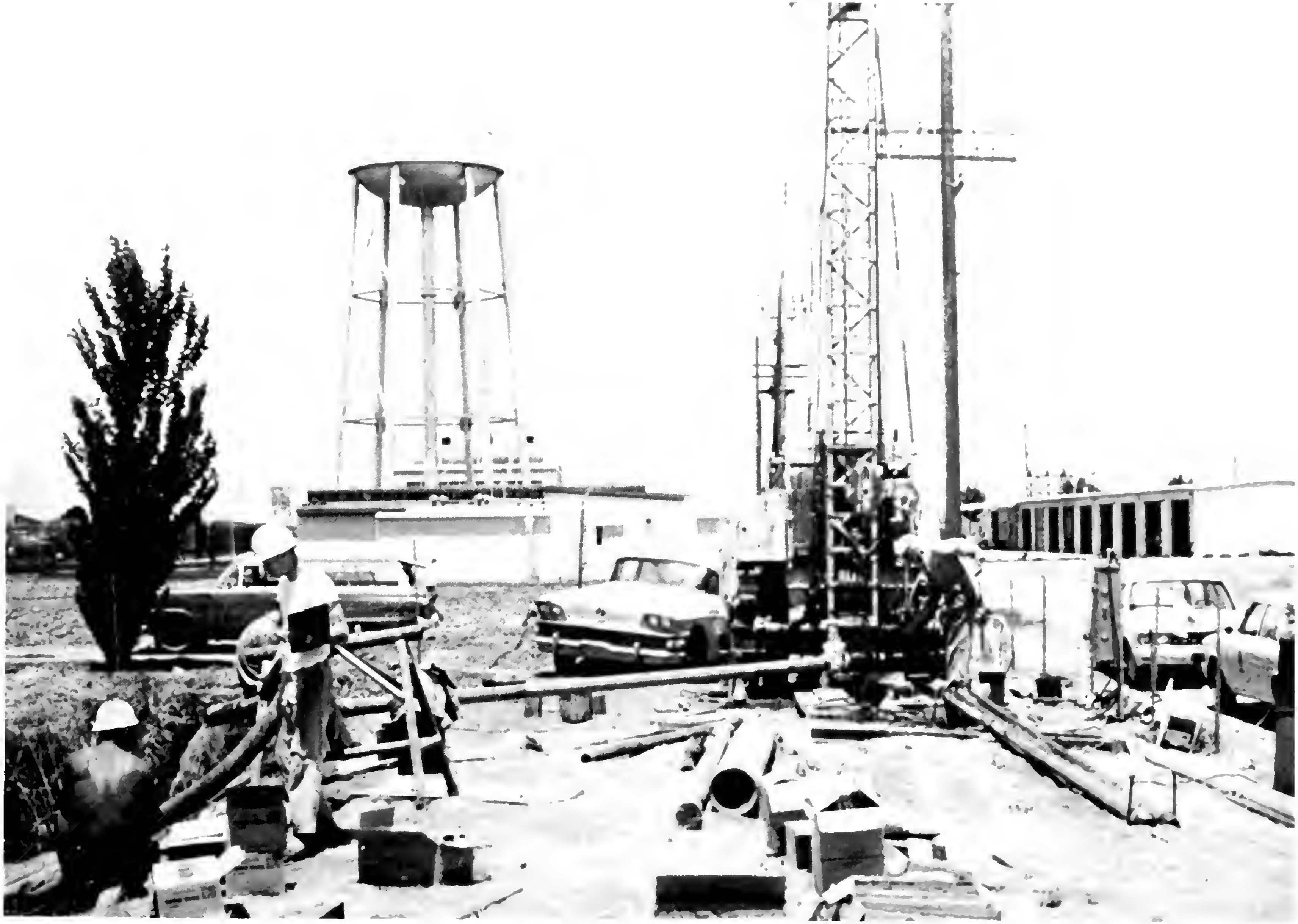
Preliminary Edition

MARCH 1965

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources



FORMATION TESTING OF AN ABANDONED WELL, June 1964

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The Resources Agency	State of California	Department of Water Resources

TABLE OF CONTENTS

Page

TABLES

FIGURES

PLATES

(plates are bound at end of report)

APPENDIXES

ATE OF CALIFORNIA—RESOURCES AGENCY WILLIAM E. WARNE, Director

EPARTMENT OF WATER RESOURCES
O. BOX 388
CRAMENTO

January 12, 1965

Honorable Edmund G. Brown, Governor
and Members of the Legislature of
the State of California

Central Valley Regional Water Pollution
Control Board

Gentlemen:

I have the honor to transmit herewith Bulletin No. 74-5 of the Department of Water Resources, entitled "Water Well Standards: San Joaquin County." The investigation leading to this report was conducted under the authority contained in Section 231 of the Water Code and at the request of interested county officials.

This is one of a series of reports designed to formulate and recommend water well construction and sealing standards for those counties of the State where regulation is deemed necessary for the protection of ground water quality. In San Joaquin County, where no such regulation exists, many water wells, which have been constructed improperly or sealed inadequately, are contributing to quality impairment of ground water by allowing interchange of water between aquifers. The report concludes that water well construction and sealing standards must be established. The standards presented are based on physical conditions and well construction practices found in San Joaquin County, and supplement the minimum standards presented in Bulletin No. 74, entitled "Water Well Standards: State of California."

The report recommends that San Joaquin County adopt and enforce, at the earliest possible date, adequate water well construction and sealing standards to insure the protection of ground water quality and that investigative work be initiated to identify and correct existing improperly constructed and abandoned water wells.

Sincerely yours,

William E. Warne

Director

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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ACKNOWLEDGMENTS

Valuable assistance and data used in this investigation were contributed by public and private agencies and individuals. This cooperation is gratefully acknowledged.

We are appreciative of the assistance of the many water well drillers in San Joaquin County who provided information pertaining to water well construction and sealing. We also are grateful to the California State Department of Public Health, Bureau of Sanitary Engineering, for assistance in preparation of standards pertaining mainly to the sanitary aspects of well construction.

Special mention is made of the helpful cooperation of the following:

United States Geological Survey, Ground Water Branch and Quality of Water Branch

Central Valley Regional Water Pollution Control Board

Board of Supervisors, County of San Joaquin

California Water Service Company

AUTHORIZATION FOR INVESTIGATION

Authority for the formulation of water well construction and sealing standards is provided by Section 231 of the State Water Code which states:

> "Section 231. The department, either independently or in cooperation with any person or any county, state, federal or other agency, shall investigate and survey conditions of damage to quality of underground waters, which conditions are or may be caused by improperly constructed, abandoned or defective wells through the interconnection of strata or the introduction of surface waters into underground waters. The department shall report to the appropriate regional water pollution control board its recommendations for minimum standards of well construction in any particular locality in which it deems regulation necessary to protection of quality of underground water, and shall report to the Legislature from time to time, its recommendations for proper sealing of abandoned wells."

CHAPTER I

INTRODUCTION

Ground water is very important to San Joaquin County. Even with the completion of the Folsom South Canal and numerous other proposed water projects, San Joaquin County's economy and growth will continue to rely on the availability of good quality ground water.

It is estimated that there are presently at least 20,000 water wells in use in San Joaquin County and an additional 500 are being drilled each year. These wells range from large industrial wells to small single-family domestic wells. Many of the new wells are poorly constructed, both from a sanitary and a structural viewpoint, others are drilled and the casings are perforated into saline zones, and are doomed to abandonment soon after completion. For every three new water wells drilled, it is estimated that one more water well is improperly abandoned and added to the unknown thousands of abandoned wells. These wells are a potential, if not immediate, source of degradation to San Joaquin County's ground water since improperly abandoned wells may permit poor quality waters to comingle with usable sources above or below the degraded aquifers.

Around and after the turn of the century the greatest detriment to the ground water of San Joaquin County had been the improper abandonment of gas wells. In August 1915, the State Division of Oil and Gas (then a part of the State Mining Bureau) was organized and controls were established to insure protection of ground water resources in the vicinity of oil and gas wells. At present many large irrigation wells are being abandoned to make way for urban and industrial development, or because their waters have become saline. In many cases the improper abandonment of these wells has caused, or could cause, problems to usable ground water in the area.

Area of Investigation

San Joaquin County, shown on Plate 1, "Location of Area of Investigation," lies at the confluence of California's two major drainage basins, the Sacramento and San Joaquin River systems in the heart of California's Central Valley. It is bordered on the north and south by broad valleys, on the east by the Sierra Nevada foothills, and to the west by the Delta and its vast waterways. Gentle rolling hills on the east merge into nearly flat lands in the central and western parts of the county. The summers are distinguished by high daytime temperatures, warm nights, and negligible amounts of rainfall. The winters are marked by moderate temperatures and rainfall.

San Joaquin County's economy is primarily agricultural. Principal crops grown are beef and dairy cattle, grapes, walnuts, alfalfa, sugar beets, asparagus, tomatoes, and barley. Industries related to the processing and growing of foodstuffs, such as canneries, wineries, packing houses, fertilizer and farm equipment factories are responsible for the bulk of San Joaquin County's industrial output. In recent years, however, a few large non-agricultural industries such as tire molding, asbestos cement pipe, clay pipes, and auto glass have built large plants. Virtually all of these industries depend on ground water for their supply. Urban areas also depend on ground water.

In the Delta Area irrigation water is obtained from nearby sloughs. The numerous streams which debouch from the Sierra Nevada foothills provide surface water to other areas. Water from these streams is closely controlled by established water rights. Since there is little, if any unappropriated water presently available, all further expansion of urban, industrial, and agricultural growth is dependent on ground water supplies or imported water.

Stockton, in the geographical center of the county, is the major urban complex. As the hub of an extensive transportation network from the early gold rush days, Stockton enjoyed early and continuous development. Lodi, Tracy, and Manteca are other important municipal areas.

For purposes of this investigation, the county was divided into four areas. These were designated the "Eastern Area," "Stockton Area," "Tracy Area," and "Delta Area." The areas are shown on Plate 2, "Topography and Subdivisions of the Investigated Area."

Related Investigations and Reports

Appendix A contains a list of publications utilized in the preparation of this report. Reference is made to these publications in the text by means of numbers in parentheses, e.g., (1). The following publications were considered to be of particular importance:

Bulletin No. 11, "San Joaquin County Investigation," published in 1955 by the State Water Resources Board. This bulletin contains information on ground water supplies and quality, geology, and plans for the ultimate development of surface waters.

Report No. 7, "Quality of Ground Water in the Stockton Area, San Joaquin County," published in 1955 by the State Department of Public Works, Division of Water Resources. This is a supplement to Bulletin No. 11 and contains water quality and geologic information peculiar to the Stockton area.

Bulletin No. 74, "Recommended Minimum Well Construction and Sealing Standards for Protection of Ground Water Quality, State of California," Preliminary Edition, published in July 1962 by the State Department of Water Resources. This bulletin contains general well construction and sealing standards for the State as a whole.

Scope of Investigation and Report

The purpose of this investigation was to obtain and assemble information necessary to formulate and recommend water well construction and sealing standards for protection of ground water quality in San Joaquin County.

This report provides an outline of the present construction practices in the county and points out shortcomings of these practices insofar as minimum requirements are concerned. As a result, local laws or ordinances may be required to correct present deficiencies.

The investigation included a review and evaluation of existing data and historical records. Special consideration was given to areas of known poor or marginal quality ground water to determine if trends in quality exist, and if so, the possible causes of such trends.

Geologic studies for this investigation were largely of a reconnaissance nature and consisted of identifying areas of ground water occurrence throughout the county. Much of the geologic data was obtained from previous investigations.

Previously compiled data were supplemented by field information obtained intermittently from 1958 to 1964. This work included:

(1) A survey of 497 active and abandoned wells to determine physical conditions and prevalent construction and sealing practices.

(2) Collection of water samples from 202 wells for bacterial analysis during the spring and again in the summer of 1959.

(3) Collection of several hundred water samples for complete or partial mineral analysis during 1959 and 1963.

(4) Interviews with water agencies -- personnel and well drillers to obtain information on well construction methods and problem areas.

(5) Interviews with personnel of seismic exploration companies and inspection of their drilling, testing, and abandonment practices.

(6) Examination and analysis of well logs and electrical logs. Well logs were filed under Section 7076 of the Water Code; E-logs were supplied by interested well drillers.

(7) Use of a formation testing device in the vicinity of the county hospital area in order to sample individual aquifers separately.

Certain terms used in this report are presented in Appendix B to facilitate understanding and to avoid ambiguities and misconception. The well numbering system utilized during this investigation and presently used by the Department of Water Resources is explained in Appendix C.

Water quality is an important consideration in evaluating well standards. Water quality criteria, as established by state, federal, or other agencies, are listed in Appendix D.

Results concerning the formation testing are described in the separately bound Appendix E. A description of the formation testing device is also included there.

Geologic, hydrologic, and water quality conditions existing in a ground water basin are among the principal factors to be considered when water well construction and sealing standards are formulated. This report contains information on the occurrence and nature of ground water and areas of specific water quality problems, present practices in well construction, recommended standards of water well construction, and sealing of abandoned wells for the protection of ground water quality in San Joaquin County.

Geology

The geologic investigation of San Joaquin County was limited to a determination of the geologic features which effect the occurrence, nature, and movement of ground water within the water-bearing deposits in the

predominant ground water producing areas. Plates 3, 4, and 5 show the areal geology and representative geologic sections in San Joaquin County. Special attention was given to geologic features which directly influence the proper construction of new, and the sealing of abandoned water wells.

Geologic formations in San Joaquin County range in age from Pre-Cretaceous to Recent Alluvium. The water-bearing deposits include the Mehrten Formation of Late Miocene and/or early Pliocene age, the Plio-Pleistocene Arroyo Seco Gravels, Laguna Formation, and Tulare Formation. Lesser quantities of ground water are obtained from the Victor Formation of Pleistocene age and the alluvium of Recent age. Ground water occurs in both confined and unconfined aquifers in the water-bearing deposits. Nonwater-bearing units consist primarily of the Pre-Cretaceous igneous and metamorphic rocks which compose the basement complex and the undifferentiated Cretaceous and Eocene marine sediments. The Pre-Cretaceous rocks are generally aquifuges or aquicludes; the sediments are inclined toward the classification of aquiclude or aquitard. The marine sediments are only slightly permeable, contain mostly saline water, and are at such depths as to make them uneconomical to pump.

Hydrology

Ground water enters all the fresh water-bearing formations in San Joaquin County by percolation of water from surface streams, by rainfall infiltration, and by percolation of unconsumed water in irrigated land.

Plates 6, 7, and 8, "Ground Water Hydrology", provide information on depth to water in wells. Historical data for 1953 are presented on Plate 6. Plate 7 shows the 1963 information. The plates indicate a general ground water movement from west, east, and south toward the Delta. This movement, however, is intercepted, and ground water levels are depressed

along much of the eastern perimeter of the Delta as a result of heavy pumping. Plate 8, "Lines of Equal Change of Depth to Water in Wells, Spring 1953 to Spring 1963", is a derivative of historical and recent data, indicating subsidence or rise of the ground water table.

Water Quality

The inherent properties of water which make it an excellent solvent of minerals are often its chief disadvantage when it comes to ground water. Undesirable dissolved solids caused by contact with minerals in the soil are major detriments to the quality of ground water. The activity of animals and men also impair the quality of ground water. Because of the dissolved impurities, the chemical behavior and potability of ground water are closely related to the various types and respective amounts of these chemicals. The criteria, as established by the various agencies, were utilized in evaluating the quality of water with regard to present or contemplated beneficial uses.

Dissolved mineral constituents in water are ordinarily dissociated into ions. Calcium, magnesium, sodium, and potassium are usually the predominant cations (positively charged ions), while the prevailing anions (negatively charged ions) consist of carbonate, bicarbonate, sulphate, nitrate, and chloride.

Mineral analyses of water are generally reported in chemical equivalents per million (epm) and parts per million (ppm). Water is often classified by determining the predominant cation and anion. For example, a water classified as calcium bicarbonate would be a water in which more than 50 percent of the total equivalent cations is calcium, and a majority of the equivalent anions is bicarbonate. If no cation or anion predominates, the

two or three highest equivalent cations or anions are hyphenated in combination. Accordingly, calcium-magnesium bicarbonate is a water in which the two dominating cations are calcium and magnesium, and bicarbonate is the prediminant anion.

The minerals listed in Table 1, Appendix D, for which the U. S. Public Health Service has set mandatory and recommended requirements for drinking water, are not generally determined in a standard mineral analysis. These minerals are not normally found in harmful quantities in ground water.

During the course of this investigation existing basic data on ground water quality in San Joaquin County were updated by resampling wells analyzed during previous investigations by the State Department of Water Resources for Report No. 7 and Bulletin No. 11. Additional wells were also included in sparsely sampled areas or in areas where no data were available. Intensive sampling was carried out in two problem areas to locate the base of fresh water between Stockton and Lathrop and the ground water containing high boron concentrations in the Tracy area.

A formation testing program was carried out in the vicinity of the San Joaquin County Hospital in an effort to determine the quality of ground water opposite each set of perforations in seven different wells. A definite separation of waters originating from different aquifers was accomplished and samples were taken to determine the water quality characteristics of each aquifer. However, it was impossible to establish the continuity of different geologic strata in a region where the finer grained Delta deposits are grading into the coarser alluvial deposits.

Results show that ground waters in the Stockton and Eastern areas are generally of satisfactory mineral quality for most beneficial uses. Due to the prevalence of high concentrations of boron in ground water in the Tracy area, the water should be checked before irrigating boron-sensitive crops. Recently there has been a deterioration in the quality of ground water between the City of Tracy and the San Joaquin River due to an increase in chloride and other mineral concentrations. In the Delta area, ground water of good mineral quality is scarce, and usually occurs in small lenses within 150 feet of the ground surface.

Plates 9, 10, and 11, "Ground Water Quality", show the quality in terms of chlorides and boron concentrations and hardness.

Sanitary Survey

In the survey to determine sanitary adequacy of construction, the condition of wells and their surroundings were noted. The condition of the wells and their surroundings were divided into three categories: good, fair, and poor. Primarily dirtiness and general appearance were considered. For example, if a well had no surface seal and there was dirt or a source of contamination nearby, a high contamination potential to the ground water supply was assumed.

During both May and July 1959, 214 selected wells throughout San Joaquin County were tested for the presence of coliform bacteria by personnel of the Department of Water Resources. Two-hundred-two wells were sampled during May. One-hundred-ninety of these same wells, plus 12 additonal wells, were sampled in July.

Bacteriological analyses of samples were made in the mobile laboratory of the Department of Water Resources in portions of five 10-millimeter

plantings. The tests used in analyzing for the coliform group conformed to the specifications in the tenth edition of "Standard Method for the Examination of Water and Waste Water".

Coliform bacteria generally originate in the intestinal tract of warm-blooded animals and, when found in water supplies, indicate the possibility of fecal pollution. The results of tests for the coliform bacteria group are expressed in terms of the Most Probable Number (MPN) of coliform organisms per 100 milliliters. The MPN is the density of coliforms most likely to produce a particular analytical result. Coliform density data in terms of the MPN are generally interpreted in the following manner:

1. Coliform densities with MPN averaging 2.2 per 100 ml or less generally indicate a bacteriologically safe water.

2. Coliform densities with MPN in excess of 2.2 per 100 ml indicate present or potential contamination.

3. The presence of coliform groups in sewage could mean that enteric pathogens from man or warm-blooded animals are also present.

Based on the sanitary survey a few observations can be made.

1. Forty percent of the samples collected during both sampling periods failed to pass U. S. Public Health Service requirements that drinking water shall contain no more than one coliform organism in 100 ml of water.

2. Less than half, or 105 out of a total of 214 wells, were observed to be free from contamination.

3. Contamination is a local rather than a widespread problem. The wells with high MPN are scattered throughout the county and follow no obvious pattern.

4. Surface sealing of wells is effective in reducing contamination of ground water. Out of the total number of wells having a surface seal, approximately 80 percent had a MPN of 2.2 or less, and only 10 percent had a MPN of 16 or greater.

Municipal wells throughout the county are sampled on a monthly basis by the local San Joaquin County Health District. Five of these municipal wells, owned by the City of Stockton in the Lincoln Village area, were included in the sampling program and were found to be free of coliform bacteria.

The survey results are summarized in Table 1.

TABLE 1

Sanitary Survey Results 1/

	Item	Most Probable Number (Coliform Bacteria Group): Less Than 2.2	2.2	5.1	9.2	16	More Than 16	Total Number of Wells Sampled
May 1959	Wells in Good Condition	71.0	12.0	7.0	1.0	3.0	6.0	100
	Wells in Fair Condition	50.6	7.6	8.9	5.1	2.5	25.3	79
	Wells in Poor Condition	38.1	14.3	9.5	9.5	4.7	23.9	21
	Wells in Unclassified Condition	50.0	50.0	0	0	0	0	2
	Number of wells sampled in each MPN group	120	22	16	7	6	31	202
	Wells with surface seal	65.2	14.8	7.8	2.6	0.9	8.7	115
	Wells with close source of contamination	48.1	7.4	7.4	7.4	0	29.7	27
	Wells with high contamination potential 2/	45.2	12.9	3.2	6.5	3.2	29.0	31
July 1959	Wells in Good Condition	79.8	5.1	5.0	2.0	2.0	6.1	99
	Wells in Fair Condition	51.9	14.2	5.2	6.5	5.2	17.0	77
	Wells in Poor Condition	56.5	8.7	4.3	0	13.0	17.4	23
	Wells in Unclassified Condition	66.7	0	0	0	0	33.3	3
	Number of wells sampled in each MPN group	134	18	10	7	9	24	202
	Wells with surface seal	70.3	11.7	3.6	3.6	1.8	9.0	111
	Wells with close source of contamination	62.5	6.3	6.3	3.1	0	21.8	32
	Wells with high contamination potential 2/	56.3	3.1	6.3	3.1	6.2	25.0	32

1/ All figures are in percent except number of wells sampled.

2/ Explained on page 9

CHAPTER II

GROUND WATER

Ground water occurs throughout San Joaquin County. The quality and availability, however, vary widely. In some areas quality problems exist, while in other areas the principal problem is the lack of sufficient water.

Eastern Area

The Eastern Area encompasses nearly two-thirds of the entire county, and lies east of the San Joaquin River extending to the foothills of the Sierra Nevada.

Occurrence

The Sierra Nevada complex is a fault block that tilted creating a mountain chain to the east and a structural trough to the west. The Eastern Area of San Joaquin County is situated in the eastern half of this trough. Stream born detritus of the highlands has been brought into this trough, called the Great Valley of California. This detritus includes sediments of Cretaceous to Recent age which now form a great wedge that is thickest in the center of the valley and feathers out against the crystalline rocks of the mountains a few miles east of the San Joaquin County line.

Cretaceous marine sediments of unknown thickness overlie the crystalline basement beneath the Eastern Area. Electric well logs indicate that these sediments contain only saline waters. Eocene sediments are present in the area, but these are mostly of marine origin and contain poor quality water.

The post-Eocene sediments yield fresh water to wells in all but the extreme western part of the Eastern Area and are therefore of major interest

in the present study. The oldest of these formations is the Valley Springs Formation which outcrops in the northeastern part of the county. It is of Miocene age and varies in thickness from 75 to 525 feet, thickening to the west. The formation yields water of good quality under limited areas in the eastern portion of the county, but due to low permeability, the yield of wells in the Valley Springs Formation is too small for irrigation purposes.

The Mehrten Formation is exposed at the surface in the eastern part of the county just west of the outcrop belt of the Valley Springs Formation. The Mehrten Formation is an important aquifer in the eastern part of the Eastern Area. Many of the sands of the Mehrten are highly permeable and furnish water of good quality to deep wells. The formation is principally composed of siltstone, sandstone, conglomerate, and some beds of unconsolidated sand and layers of volcanic agglomerate probably derived from mudflows. "Black sands," (so named because of their high content of andesitic grains) are reported in logs of wells extending into the Mehrten Formation. In the Mokelumne River area the thickness of the formation varies from 75 to over 400 feet. This thickness appears to increase southward and westward. The formation dips somewhat less than 100 feet per mile in a southwesterly direction.

The Mehrten aquifers receive percolation from a three-mile-long reach of the Mokelumne River east of Clements from the Calaveras River between one mile west of Bellota to five miles east of Bellota, from Farmington Reservoir on Littlejohns Creek, and from numerous small streams in the outcrop area of the formation. West of this area water in the Mehrten aquifers is partially confined by relatively impervious strata. The water level of wells in the Mehrten Formation appears to be little different from that of nearby shallower wells.

The Laguna Formation underlies the area of gently rolling hills between the outcrop area of the Mehrten Formation and the more recent sediments of the alluvial plain of the Eastern Area. The Laguna Formation is largely composed of stream-laid sand and silt, but also contains some gravel and clay. Its composition varies markedly both vertically and laterally. The formation dips westward throughout most of the Eastern Area and is essentially in conformity with the underlying Mehrten Formation. Like the Mehrten Formation, it also thickens noticeably to the west. The thickness of the Laguna at its outcrop area, in the vicinity of the Mokelumne River, is 0-400 feet according to the United States Geological Survey.

The hydrologic characteristics of the Laguna Formation are variable. Bodies of perched water are common in its outcrop area. Wells penetrating one or several of the blue clay strata west of its outcrop are characterized by pressure effects.

The Arroyo Seco Gravel is a thin unit between the Laguna and Victor Formations. Its outcrop consists of weathered cobbles, sand, and gravel. The formation is believed to have once covered an extensive pediment, now partly buried beneath the Calaveras and Mokelumne alluvial fans. Like the Laguna Formation, the Arroyo Seco is believed to thicken westward as it dips further beneath the ground. Sediments of Arroyo Seco age undoubtedly yield water to some wells, but such sediments cannot be differentiated in logs from underlying and overlying formations. For this reason it has not been shown as a separate unit on the geologic map (Plate 3). It is inferred that the Arroyo Seco Gravel is a coarse fraction of rock waste that was transported from the Sierra Nevada after the Sierran block was again tilted in middle Pleistocene time.

The Quaternary alluvial sediments deposited since the Arroyo Seco Gravel, excluding the present stream channel deposits, have been mapped as one unit (Plate 3). Pleistocene alluvium is called the Victor Formation. The alluvial fan deposits are composed of sand, gravel, silt, and clay. The fan deposits were laid down by the various streams debouching from the Sierra Nevada and depositing material on their growing alluvial fans. The sand and gravel stringers represent active channels of the distributaries in which the coarser sediments were deposited. Silt and clay deposits represent areas between the active distributaries. In these areas deposits were made only at times of inundation. The position of the active channels shifted continually during the process of building the alluvial fans, and an interfingered network of sand and gravel stringers resulted. The many stringers generally end abruptly, both laterally and vertically, making correlation of well logs often impossible. The Quaternary alluvial sediments have a maximum thickness of approximately 100-125 feet along the western edge of the Eastern Area. Despite the thinness of this unit a number of wells obtain large yields from the sand and gravel stringers; however, most of these wells also penetrate the underlying Laguna, and in many cases the Mehrten Formation.

The only importance of the recent sand, gravel, silt, and clay deposits in the active stream channels is that they transmit water to underlying permeable formations.

Most water used in the Eastern Area is drawn from the Arroyo Seco, Laguna, and Mehrten Formations. The ground water obtained from these formations is continually being recharged by percolation from surface waters which originate in the Sierra Nevada or adjacent foothills.

Over the past few decades, the quantity of ground water available has changed. This change is reflected in the change of depth to water and

is illustrated by Plate 8 for the 10-year period 1953-63. The lowering of water levels has been caused by discharge from aquifers exceeding ground water recharge. Increased use for irrigation and domestic needs in the Eastern Area itself, and the concurrent lowering of the water table at the western boundary of this area, are responsible for this condition. The low water table on the west, around Stockton, resulted in further steepening of ground water gradients. This additional increase in gradient increased the adverse effect of local overdraft within the Eastern Area.

The detrimental effects of this lowered ground water table on the ground water users have been:

(1) Higher costs of pumping

(2) Increased costs for well construction

(3) Increased capital costs for pumps and appurtenances.

Water Quality

The ground water in the Eastern Area of San Joaquin County is almost without exception of excellent quality for all present beneficial uses. The total dissolved solids content of water sampled for irrigation wells ranges from 120-550 ppm and averages about 200 ppm. Table 2 contains analyses of representative ground water samples taken from the Eastern Area. The locations of the wells sampled are indicated on Plates 9, 10, and 11.

In general, the domestic wells sampled were found to contain water conforming to the standards for chemical substances in drinking water set by the United States Public Health Service. Some localized instances were noted where individual domestic supplies contained excessive concentrations of coliform bacteria and nitrates apparently caused by a combination of poorly constructed wells, or wells in general disrepair, allowing irrigation return flow and septic tank effluent to seep into them.

Ground Water in the Eastern Area is generally of moderate hardness, with most wells ranging between 50-200 ppm expressed as calcium carbonate ($CaCO_3$). Two centers of excessive hardness are the areas in the vicinity of Waterloo and Peltier Roads north of Lockeford. In these two areas wells were found to contain water with hardness ranging between 200-700 ppm. The water quality with respect to hardness is shown on Plate 10.

Because there are very limited data available on ground water quality in the Eastern Area prior to the late 1940's, it is impossible to determine any overall trends other than for the 1949-1963 period. No permanent increases in any of the minerals for which analyses were made could be detected for the 1949-1963 period.

The Mokelumne and Calaveras Rivers, that originate in the Sierra Nevada, recharge the ground water basin with excellent quality waters. Table 3 illustrates the present high quality of waters obtained from these streams.

TABLE 2

Mineral Analyses of Representative Ground Waters in the Eastern Area of San Joaquin County

State Well Number	Depth of Well	Date of Sample	Conductance $Ec \times 10^6$ at 25°C	Ca	Mg	Na	K	Cl	SO_4	NO_3	HCO_3 & CO_3	B	SiO_2	Total Dissolved Solids (ppm) a/	Percent Sodium
				Mineral Constituents in Parts Per Million											
5N/8E-31J1		7/16/62	185	12	9.6	14	2.5	6.0	5.0	5.8	88	0.0	60	159	31
4N/6E-11P1	200	7/16/62	240	20	10	14	1.6	12	2.9	3.3	115	0.1	64	185	28
4N/7E-23B2	325	7/16/62	252	17	7.2	20	2.5	11	0.5	5.2	115	0.1	67	188	36
4N/8E-18D1	220	6/4/59	426	32	18	26	1.5	36	4.0	23	165	0.0	48	270	27
3N/7E-11G1	339	8/5/60	203	14	7	15	3.1	10	5	3	97	0.0	44	149	31
3N/8E-8E1	460	8/5/60	169	11	5	14	1.5	11	1	1	76	0.0	38	120	38
2N/7E-14N1	535	7/16/58	284	26	14	5.4	4.4	4.2	0.2	0.6	167	0.0	65	202	8
2N/8E-15L1	680	7/16/62	235	21	7.8	12	6.3	1.8	2.9	3.8	125	0.0	60	178	21
2N/9E-7G1	700	7/26/62	270	29	9.0	11	3.1	7.4	12	0.0	133	0.1	47	184	17
1N/7E-12C1	536	7/16/62	315	25	11	19	3.8	8.9	5.3	2.8	152	0.1	59	212	27
1N/9E-18G1		7/6/62	208	15	6.6	13	2.8	7.8	2.4	15	81	0.1	69	172	29
1S/7E-13A1	352	5/5/59	251	20	7.3	16	3.4	15	7.1	7.4	102	0.2	67	194	29
1S/9E-8H1	340	7/26/62	320	17	6.6	19	2.9	11	9.1	8.0	100	0.2	69	192	36
2S/6E-3F1	94	3/19/59	387	32	6.8	38	20	34	8.7	0.6	163	0.3	29	232	43
2S/8E-11R1		6/9/59	246	21	6.0	16	2.2	2.9	26	42	58	0.1	64	208	30
2S/9E-10F1		6/9/59	254	22	7.5	21	2.1	2.3	6.2	8.6	143	0.1	42	182	34

a/ Determined by addition of analyzed constituents.

TABLE 3

Mineral Analyses of Representative Surface Waters in the Eastern Area of San Joaquin County

	Date of Sample	Conductance $Ecx10^6$ at 25°C	Mineral Constituents in Parts Per Million										Total Dissolved Solids (ppm) a/	Percent Sodium
			Ca	Mg	Na	K	Cl	SO_4	NO_3	HCO_3 & CO_3	B	SiO_2		
Calaveras River	5/6/63	181	21	7.2	5.4	1.5	4.5	12	0.2	94	0.0	15	121	12
at Jenny Lind	9/11/63	214	27	8.3	6.1	2.5	6.0	14	1.5	120	0.0	18	140	11
Mokelumne River	5/6/63	45	5.6	0.6	2.2	0.7	2.9	1.0	0.2	21	0.0	11	35	22
near Lancha Plana	9/11/63	32	3.8	0.5	2.4	0.7	2.8	3.0	0.0	14	0.0	9.9	28	29
Mokelumne River	5/7/63	46	5.0	1.1	2.7	0.6	1.1	4.8	0.9	21	0.0	12	40	25
at Woodbridge	9/11/63	37	4.0	0.7	1.9	0.7	1.8	0.0	0.4	17	0.0	8.9	29	22

a/ Gravimetric Determination

Tracy Area

The Tracy Area lies in the southwestern portion of the county. The area is underlain by alluvial material principally deposited by intermittent streams flowing eastward from the Coast Range. The sequence of water-bearing sediments in this area is shown on Plate 5.

Occurrence

A series of northwest-trending mountains composed of sedimentary, metamorphic, and associated intrusive and volcanic rocks are in the southwest portion of the Tracy Area. These mountains are in the central part of the Coast Range. The plain south of the Delta Area and west of the San Joaquin River comprises the remainder of the Tracy Area. This plain is an important ground water producing area in San Joaquin County and received most of its younger continental sediments from the older rocks of the Coast Range.

The most important water-bearing sediments are the continental Plio-Pleistocene Tulare Formation. The Tulare Formation crops out on the west side of the San Joaquin Valley and extends north to the Delta. The formation is composed largely of clay, silt,and sand lenses containing ill-sorted deposits of sand and gravel. The recent alluvium is of lesser importance as a source of ground water. It is generally less than 100 feet in thickness. Some domestic wells obtain water from their shallow, unconfined aquifers, but most large irrigation, industrial, and municipal wells penetrate deeper into both the upper and lower portions of the Tulare Formation. The lithologic characteristics of the Tulare Formation and the overlying alluvium are similar, thus making it hard to distinguish between the two deposits. All of the formations older than the Tulare Formation are of marine origin and not fresh water-bearing.

Near or at the top of the Tulare Formation an extensive clay bed exists separating the continental sediments into upper and lower aquifers. This is shown on the geologic section, Plate 5. The lower aquifer is confined by this clay bed, the Corcoran Clay, member of the Tulare Formation. Most water well drillers log the Corcoran Clay as "blue clay." This clay is considered to be of Pleistocene age. An important distinguishing feature of the Corcoran Clay is the large amount of diatoms it contains. The clay is well sorted with a noticeable absence of sand. Marginal zones, however, have lenses of sand, silt, and gravel interfingering with the clay bed. The clay was formed, for the greater part, in fresh water as a lacustrine deposit. Its thickness ranges from 10 to 160 feet.

Recharge to the unconfined aquifers in the Recent Alluvium and upper Tulare is by the infiltration and percolation of water from rainfall, streams, and excess irrigation. This infiltrating water cannot permeate the Corcoran Clay and is recovered by wells drawing from the upper water-bearing zone. The recharge area for the confined aquifers is along the foothills where the Tulare Formation outcrops, and the Corcoran Clay is absent. Movement of ground water in the Tracy Area is in a general northeasterly direction toward the Delta Area.

Water Quality

The quality of ground water in the greater part of the Tracy Area leaves much to be desired as a good source for agricultural or domestic supplies. The water used for irrigation generally falls within the Class 2 category of "good to injurious." Table 4 contains analyses of representative ground water samples taken from the Tracy Area. The locations of wells sampled are indicated on Plates 9, 10, and 11.

In general the wells which supply the City of Tracy produce water of better than average quality for this area. An analysis of typical city water is as follows; total dissolved solids 500 ppm, chlorides 75 ppm, total hardness 190 ppm. Outside the city limits water containing total dissolved solids in excess of 1,000 ppm and total hardness above 500 ppm is common.

Water used for irrigation has been affected by dissolved solids, high chloride, sodium, and boron concentrations. During 1963, approximately 75 wells in the Tracy Area were sampled for boron. Plate 11 shows that boron is an areal problem with concentrations generally increasing toward the foothills. In the process of collecting samples for boron analysis, it was discovered that many large irrigation wells east of Tracy were deteriorating in quality, and a few of them had been abandoned. These abandoned wells are a potential hazard and may provide a conduit for poor quality waters to enter a previously good quality aquifer.

The problem of excessive amounts of boron both in the soil and in the water is not new to the Tracy Area or the San Joaquin Valley as a whole. Although boron is not generally regarded as a hazard to human beings,[1/] it can be injurious to plants. As early as 1922, observations made in the vicinity of Bakersfield established that boron applied to plants in the form of borax, along with fertilizer, was the cause of injury to plants. This and later observations led to an investigation of the valley between Stockton and the Tehachapi Mountains conducted by Mr. Frank M. Eaton of the U. S. Department of Agriculture in the early 1930's. The results confirmed that high boron concentrations were prevalent in the soil and ground water on the west side of the San Joaquin Valley.

[1/] State Water Quality Control Board, "Water Quality Criteria," Page 147 1963

Samples from the San Joaquin River and the Old River near Tracy do not show high boron concentrations. Some surface waters, such as Corral Hollow Creek, however, indicate that the ground water may be adversly affected by the soils and recharge from surface waters on the southwest side of the area. Table 5 illustrates the present quality of waters obtained from these streams.

TABLE 4

Mineral Analyses of Representative Ground Waters in the Tracy Area of San Joaquin County

State Well Number	Depth of Well	Date of Sample	Conductance $Ecx10^6$ at 25°C	Mineral Constituents in Parts Per Million										Total Dissolved Solids (ppm) a/	Percent Sodium
				Ca	Mg	Na	K	Cl	SO_4	NO_3	HCO_3 & CO_3	B	SiO_2		
2S/4E-28H1	279	3/20/59	2900	95	108	420	3.4	295	935	1.9	272	5.4	32	2030	57
2S/4E-35M1 b/	238	4/21/59	3310	14	19	554	175	449	543	4.0	430	1.7	5.2	1980	78
2S/4E-36P1	695	7/27/62	1290	73	35	143	3.5	126	299	12	169	1.3	28	803	48
2S/5E-9Q1	250	3/19/59	2410	66	84	362	3.7	251	595	16	404	6.3	25	1610	60
2S/5E-22Q1	1136	7/27/62	1250	60	36	157	3.0	222	196	14	140	1.0	33	790	53
2S/5E-29A1	242	5/20/59	788	58	15	78	2.7	94	89	16	172	1.1	26	464	44
3S/5E-8L1	265	7/27/62	820	58	26	78	2.5	98	89	64	152	0.8	40	531	40
3S/5E-9N1	555	7/27/61	1100	78	40	92	3.6	141	176	33	195	1.8	24	686	35
3S/5E-24F1	1100	7/27/62	1350	113	36	125	1.8	99	377	32	177	0.9	22	893	38
3S/6E-15M1	887	4/10/59	971	78	24	86	2.4	103	178	9.8	180	0.9	31	601	38
3S/6E-17Q1	900	4/10/59	2480	142	61	274	5.0	668	153	4.8	128	0.8	29	1400	49
3S/6E-22Q1	879	8/17/61	638	52	15	62	1.8	34	117	11	190	0.6	26	412	41
4S/6E-5Q1	721	4/10/59	646	46	20	56	1.8	39	95	32	173	0.6	23	399	38

a/ Gravimetric Determination
b/ Abandoned Well

TABLE 5

Mineral Analyses of Representative Surface Waters in the Tracy Area of San Joaquin County

	Date of Sample	Conductance $Ecx10^6$ at 25°C	Ca	Mg	Na	K	Cl	SO_4	NO_3	HCO_3 & CO_3	B	SiO_2	Total Dissolved Solids (ppm) a/	Percent Sodium
			Mineral Constituents in Parts Per Million											
San Joaquin River at	5/13/63	114	7.6	4.1	8.4	1.5	8.5	6.0	1.0	45	0.1	16	81	33
Mossdale Bridge	9/10/63	819	46	18	94	4.2	136	49	1.3	171	0.1	25	468	51
Corral Hollow Cr.	1/6/59	1760	61	46	274	7.7	156	391	1.0	370	4.2	19		63
3S/5E-19	11/6/63	2240			357			572	7.5					
Old River	5/13/63	183	12	5.4	16	1.9	19	16	2.3	55	0.1	15	125	39
near Tracy	9/10/63	1000	54	25	110	4.8	174	76	1.9	189	0.1	23	603	50

a/ Gravimetric Determination

Delta Area

The Delta Area lies in the northwest portion of San Joaquin County. The area is a structural basin that has received sediments from many sources, including the San Joaquin River. As the sediments built up, the trough of the basin sank, maintaining the Delta channels at near sea level.

Occurrence

Delta deposits, underlying the area shown as "Flood Basin Deposits" on Plate 3, are the distinguishing geologic feature of the Delta Area. These Delta deposits include all of the fine-grained sediments of post-Mehrten age. The Recent Alluvium, the Victor, and the Laguna Formations in the eastern Stockton Area and the continental sediments in the Tracy Area are contemporaneous with the Delta deposits. The undifferentiated nature of the Delta deposits makes the identification of their age difficult.

The upper portions of the Delta deposits are comprised of recent stream channel and some flood basin deposits. The stream channel deposits, composed of clay, silt, and sand, have low permeability. Deposition of this material took place in overflow basins during flood stage periods. The Delta deposits are of considerable thickness, often in excess of 1,000 feet. They are predominately silt but contain interbedded sand and gravel bodies.

The contact between the Delta deposits and the coarser alluvial deposits is interfingered with depth. Ground water in the Delta Area occurs in a series of poorly connected sand and gravel lenses, locally confined by silts and clays, causing artesian effects in some localities. The large percentage of fine-grained materials and the lenticular nature of the deposits result in low permeability. Wells located in this material usually yield only moderate quantities of water with large draw-downs. The base of the fresh water is quite shallow and generally coincides with the base of the peat

deposits. It is difficult to obtain a sufficient amount of suitable quality water for domestic and irrigation purposes in a large portion of the Delta Area.

Before the construction of the many flood control features on tributaries upstream from the Delta, floods were common each winter. Although these floods, becoming less frequent with the advent of each new upstream dam, caused much damage, they were a source of recharge to the ground water basin within the Delta Area. Recharge is now primarily from irrigation return flows and seepage from adjacent sloughs which often have high concentrations of pesticides and agricultural chemicals. Recent fish kills in the vicinity of Stockton point out the septic condition of many of the sloughs and rivers during the summer, when runoff is at a minimum and waterways are overloaded with human, industrial, and agricultural wastes.

Since many of the domestic wells in the Delta Area are less than 100 feet in depth, there may be insufficient natural filtration through an adequate depth of soil to prevent contamination from human and animal waste.[1/]

Saline waters are found throughout all depths in the Delta deposits except for the thin lenses of fresh water extending usually to a depth of less than 150 feet. It appears that the deltaic sediments were deposited in marine or brackish water. The fine-grained nature of the sediments has prevented the saline water from being replaced by the better quality water of the fresh water sloughs within the Delta and by the good quality water surrounding the Delta Area.

Fresh water recharge to the Delta Area is obtained from infiltration of rainfall and excess irrigation water.

1/ "Sanitation Guide for Small Water Systems," California State Department of Public Health, July 1953.

Water Quality

Ground water of suitable quality is becoming increasingly difficult to find in the Delta Area. According to several well drillers, water of suitable mineral quality could once quite easily be found on some of the islands. It is almost impossible to find now.

Most fresh ground water is contained in small pockets surrounded by saline water. If the withdrawal rate exceeds the rate of recharge, the fresh water pockets are replaced and degraded by the surrounding saline waters. Waters from the fresh water lenses are classified as calcium-magnesium sodium bicarbonate water. The poorer quality ground waters contain large amounts of dissolved solids. Sodium chloride waters typify the saline waters of the area. Table 6 illustrates the mineral quality of ground waters. Results of mineral analyses of representative surface waters are shown in Table 7. The surface waters are generally of the same type as the ground waters, but have less total dissolved solids. Generally, no single cation predominates. In the spring, bicarbonate is the dominant anion. During late summer the surface water deteriorates and becomes sodium, chloride-bicarbonate water.

TABLE 6

Mineral Analyses of Representative Ground Waters in the Delta Area of San Joaquin County

State Well Number	Depth of Well	Date of Sample	Conductance $Ecx10^6$ at 25°C	Mineral Constituents in Parts Per Million: Ca	Mg	Na	K	Cl	SO_4	NO_3	HCO_3 & CO_3	B	SiO_2	Total Dissolved Solids (ppm) a/	Percent Sodium
5N/5E-33J1	140	4/15/59	365	9.4	4.7	67	1.2	9.2	0.0	0.9	218	1.0	35	236	76
4N/4E-14C1	628	7/19/59	990	17	5.6	200	1.3	3.0	20	0.0	221	1.6	28	588	87
4N/5E-8H1	70	7/19/62	5200	307	206	498	2.0	1679	0.5	0.0	396	1.0	31	2919	40
3N/4E-22Q1		4/6/59	430	23	30	41	0.4	26	1.2	1.0	233	0.4	58	285	39
3N/5E-9Q1	70	4/8/59	1020	71	51	81	0.9	94	61	1.2	435	0.1	55	630	31
2N/4E-21G1	80	4/8/59	1010	66	44	95	3.6	82	0.0	0.6	531	0.6	47	600	37
2N/5E-35M2	80	4/8/59	6350	312	122	838	10	2110	0.0	1.3	168	0.8	45	3520	58
1N/4E-3N1	178	7/20/62	1210	44	26	200	1.5	158	8.0	3.6	477	1.2	29	713	67
1N/5E-28A1	200	4/8/59	3120	50	81	468	2.5	869	85	1.4	204	0.9	31	1690	69
1S/4E-14M1	273	7/20/62	1450	22	13	290	0.9	174	264	0.0	250	1.6	24	916	85
1S/5E-10H2	47	7/20/62	1140	89	47	74	2.2	205	89	0.0	233	0.1	31	652	30

a/ Gravimetric Determination

TABLE 7

Mineral Analyses of Representative Surface Waters in the Delta Area of San Joaquin County

	Date of Sample	Conductance $E \times 10^6$ at 25°C	Mineral Constituents in Parts Per Million										Total Dissolved Solids (ppm) a/	Percent Sodium
			Ca	Mg	Na	K	Cl	SO_4	NO_3	HCO_3 & CO_3	B	SiO_2		
Little Pocato Slough at Terminous	5/6/63	116	9.6	4.6	5.7	1.2	7.6	7.0	0.6	49	0.0	17	87	22
	9/11/63	232	16	9.2	18	1.4	18	7.0	0.4	101	0.0	20	136	33
Stockton Ship Channel on Rindge Island	5/6/63	255	16	6.8	24	2.0	28	23	1.4	73	0.1	14	155	42
	9/11/63	504	29	12	50	3.6	77	13	2.0	122	0.1	6.6	287	46
San Joaquin River at Garwood Bridge	5/13/63	132	10	4.0	9.3	1.6	12	7.4	0.9	48	0.0	16	87	31
	9/11/63	809	47	17	91	5.2	130	31	4.4	180	0.2	19	469	51
Grant Line Canal at Tracy Road Bridge	5/13/63	125	9.6	3.6	10	1.6	12	7.0	2.0	47	0.1	16	97	35
	9/10/63	934	49	22	105	4.0	162	66	1.8	180	0.1	26	555	51

a/ Gravimetric Determination

Stockton Area

The Stockton Area lies in the center of the county and includes the heavily urbanized metropolitan area of the city.

Occurrence

The geologic formations underlying the central and eastern portion of the Stockton Area are a continuation of the Recent Alluvium, Victor, Arroyo Seco Gravel, Laguna, Mehrten, and Valley Springs Formations of the Eastern Area. This is illustrated on Plate 4.

Ground water in the western portion of the Stockton Area is stored, for the most part, in fine-grained deltaic deposits. Generally the water is too saline for most beneficial uses, but shallow pockets of fresh water do exist.

Usable ground water in the central and eastern portion of the Stockton Area is stored to a depth of approximately 1100 feet in the unconsolidated Alluvium, Victor, and Laguna Formations. These formations are not homogeneous sediments, but are composed of discontinuous sand and gravel layers separated by variable thicknesses of sandy silt, silt, and clay. Underlying this upper fresh-water bearing section is a deep zone of saline water stored in the semi-consolidated Mehrten and Valley Springs Formations and in the Eocene and Cretaceous sediments. Ground water is replenished largely by subsurface movement of water that has percolated into the ground in the Eastern Area. Lesser amounts can be attributed to local precipitation and percolation of applied water.

The principal difference in the physical character of the sediments in the water-bearing formations beneath the Stockton and the Eastern Areas is in the coarseness of their grain. A gradual change in an east to west

direction from coarse to fine grained has been noted by a comparison of well logs. The fresh water - saline water contact found at depth beneath the central portion of Stockton rises sharply to the west as shown in the Geologic Section, Plate 4. Fine grained material of low permeability may be responsible for the "barrier" effect which apparently is preventing salt water intrusion from the west into the fresh ground water aquifers beneath the central and eastern part of the City of Stockton. Another explanation may be that a fault zone is causing the "barrier." However, there is no geologic information available at this time to confirm the presence of a fault. This "barrier" was first discussed in Report No. 7 (5).

As can be observed on Plates 6 and 7, showing depth to water in wells for spring 1953 and spring 1963, the ground water depression since 1953 has increased by an average of 20-25 feet beneath the City of Stockton. Undoubtedly there has been an increase in the hydraulic gradient across the "barrier," but well measurements in the spring of 1963 were insufficient in number to make a quantitative comparison. The gradient of 45 feet per mile, reported for 1953, was based on a horizontal distance of less than a mile across the "barrier." Since Report No. 7 (5) was published, Tillie Lewis Foods, a large canning factory located on the west side of the "barrier," has contracted with California Water Service Company for all its water needs because of the poor quality ground water on its property. This large canning factory no longer pumps on the west side of the "barrier" which would tend to increase further the hydraulic gradient across the "barrier."

Despite the increase in the ground water depression in the Stockton Area and apparent increase in the hydraulic gradient across the "barrier," no noticeable general degradation of the fresh water or fresh water aquifers has been observed east of the "barrier" beneath the Stockton or Eastern Areas.

Lateral migration of saline water across the "barrier" has not been clearly observed. This does not mean that some migration may not have already occurred, and there is no assurance that the "barrier" will continue to be effective in preventing future degradation. Considerable additional information is needed concerning the exact location and nature of the "barrier" before conclusive appraisal of the conditions may be accomplished.

Water Quality

Ground water east of the "barrier" is obtained from the Victor and Laguna Formations, and is generally of good to excellent mineral quality. Ground water in the Stockton Area contains slightly higher dissolved solids than water in the Eastern Area. In some of the western portions the water quality resembles that of the Delta Area.

Most of the ground water contained in the Victor and the Laguna Formations above 600 feet is calcium-bicarbonate. Water contained in the Laguna Formation between 600-1100 feet is sodium-bicarbonate in nature and generally contains dissolved solids less than 300 ppm. Ground water below 1100 feet is seldom of suitable quality for industrial or domestic use. These are sodium-chloride waters with dissolved solids ranging between 700-3000 ppm. The dissolved solids generally increase with depth in the deeper Mehrten and Valley Springs Formations.

The contact between the fresh and saline waters slopes steeply upward toward the west along the "barrier." The exact depth of contact varies both in a north-south and east-west direction. This is illustrated on Plates 4 and 5. West of the "barrier" the point of contact is practically at ground level, and fresh water is found only in isolated pockets.

The exceptions to good quality ground water east of the "barrier" usually occur in localized areas degraded by poor quality waters. These

waters may be connate waters that have entered the once good quality aquifers through abandoned gas or water wells. The upward migration of saline, connate waters through conduits, such as abandoned gas wells, is attributed to the high piezometric level of the connate waters. Some of the gas wells drilled in the early 1900's were abandoned because of decrease in pressure. These wells were known to produce water under artesian flow and their abandonment provided conduits for the rise of connate water.

During this survey the existence of an abandoned gas well was established which may still be degrading fresh water aquifers. The well is presently inaccessible, being located under a large building; hence, the condition of the well is unknown. Two neighboring water wells, each 350 feet deep, produce good quality water with chlorides and total hardness averaging 50 ppm. One of these three wells is shallower (250 feet in depth) and the other two are deeper (1000 feet $\pm$, with perforations below 500 feet) than the two poorer quality wells. This suggests that the abandoned gas well has degraded the ground water only in the 350 foot interval since no sign of degradation is evident either at or above the 250 foot depth, or at or below the 500 foot depth.

The California Water Service Company has been keeping records of water quality analyses on its wells in the City of Stockton since the early 1930's. Presently most wells are sampled on a once-a-year basis. Wells suspected of degrading water quality are analyzed more frequently, and various pump tests are performed on these wells. Wells producing poor quality water are permanently sealed with an impermeable material if the water quality cannot be improved.

Since 1956 an iodide analysis and a standard mineral analysis have been run annually on each well. Connate waters of marine origin are on the

average about 30 times higher in iodide concentrations than ocean waters (18). In ocean water the iodide/chloride ratio is 1:380,000 whereas in connate waters of marine origin the ratio is usually between 1:33,000 to 1:50. The records of iodide analyses enable personnel of the California Water Service Company to determine the origin of saline water in their wells and the rate of change in connate water concentrations. Based on this assumption all analyses to date indicate that saline water in their wells originates as connate water, not as ocean water intrusion.

Complete mineral analyses on wells owned by the city in the Lincoln Village area are done on an intermittent basis by outside, interested agencies such as the State Department of Water Resources. Recent analyses show these wells to be of excellent mineral quality.

Table 8 shows the results of mineral analyses of representative ground waters in the Stockton Area.

TABLE 8

Mineral Analyses of Representative Ground Waters in the Stockton Area of San Joaquin County

State Well Number	Depth of Well	Date of Sample	Conductance $Ec \times 10^6$ at 25°C	Mineral Constituents in Parts Per Million										Total Dissolved Solids (ppm) a/	Percent Sodium
				Ca	Mg	Na	K	Cl	SO_4	NO_3	HCO_3 & CO_3	B	SiO_2		
2N/6E-20J1	246	4/17/59	388	36	13	23	3.5	15	18	0.2	194	0.1	40	244	25
2N/6E-21F1	519	4/15/59	685	67	30	30	1.7	39	94	5.6	245	0.2	54	442	18
2N/6E-27L1	519	7/19/62	360	24	8.5	34	3.5	7.1	9.1	1.4	176	0.2	42	219	43
1N/6E-3H3	961	9/1/59	638	22	9.5	97	1.0	118	0.2	0.6	172	0.6	34	367	69
1N/6E-4D1	575	9/1/59	566	10	3.9	111	1.3	76	0.3	0.3	216	0.6	60	370	85
1N/6E-10P1	1130	7/29/62	2950	125	51	461	7.5	993	3.0	0.0	147	0.9	53	1767	67
1N/6E-14H1	418	9/1/59	410	11	2.3	78	1.2	39	0.0	0.4	189	0.6	62	288	81

a/ Gravimetric Determination

CHAPTER III

PRESENT WELL CONSTRUCTION AND SEALING PRACTICES

In the spring and summer of 1959, a survey was conducted by the Department of Water Resources on the existing well construction and sealing practices in San Joaquin County. During this survey on-site inspections were made of 497 wells throughout the county. These wells included 41 municipal, 247 domestic, and 209 irrigation wells. Wells were inspected to determine: (1) Methods and materials used in their construction, (2) Physical condition, (3) Sanitary conditions surrounding the wells, and (4) Whether adequate provisions had been made to prevent the entrance of poor quality or polluted surface waters into each well. This information was supplemented by personal interviews during 1963 with most of the well drillers operating in San Joaquin County, and by data obtained from "Water Well Drillers Report" forms submitted under provisions of Section 7076 of the Water Code. At the time of the interview most drillers filled out a questionnaire on their current drilling practices.

The results obtained from the well construction survey, interviews, and review of the well logs indicate that in many instances well construction and sealing practices are not adequate to protect the ground water from degradation.

Well Location

Drillers were asked what they considered to be a safe distance to locate a well from a source or sources of contamination. Most drillers stated that wells should be located at least 50 feet from septic tanks and sewer lines and 100 feet from cesspools and privies. The information from the well construction survey indicated that wells are often located too close to sources

of contamination. Thirty percent of all wells surveyed were less than 50 feet from sources of contamination. Sources of contamination considered in the construction survey included chicken yards, barnyards, etc., in addition to septic tanks and cesspools. All drillers stated that they try to locate wells on topographic high places in order to facilitate good drainage away from the wells. The construction survey supported this statement and 88 percent of the wells were found to have good surface drainage.

Drilling Methods

The cable tool and the rotary method of drilling are used almost exclusively in San Joaquin County at the present time. A tabulation of well logs showed 60 percent of the wells drilled by the cable tool method. In the Delta Area, the combination of a shallow ground water table and organic soils has made it feasible for a few wells to be driven.

Casing

Steel is the most common well casing material used by the drillers operating in San Joaquin County. Almost all wells presently drilled in this county are cased at least 50 percent of their total depth with a steel casing. The common practice is to drive the casing until, in the driller's opinion, an impervious clay layer, suitable to seat the casing, is reached. The remainder of the well is then drilled and left uncased, provided the soil is consolidated enough not to cave into the well. In the event clay suitable to seat the casing is not found, the casing is usually extended to the full length of the well and a footing of concrete or grout is provided.

The present trend is toward the use of casings in lengths of up to 20 feet. Three or four years ago the popular length for each section of casing was four feet. An increasing percentage of the longer casings presently used

is imported. No attempt was made during this investigation to compare the strength, durability, or corrosive resistance of casings made specifically for water wells.

A review of well logs filed under Section 7076 indicates that 14, 12, and 10 are the popular gage numbers for casings, although 1/4 and 3/16 inch casings are also common. The lighter 14 gage is usually limited to domestic wells drilled by the rotary method. These wells are normally six inches or less in diameter and are usually less than 150 feet in total depth. The 12 and 10 gage casings are used most commonly in wells drilled by the cable tool method. The heavier 3/16 and 1/4 inch casings are found only in the deeper gravel packed wells.

With the exception of a few industrial, municipal, and large gravel packed irrigation wells, it is common practice to use single, rather than double-walled casing. Most widely used casing joints are the butt and the collar welds. Threaded collars, pick joint, and lug weld are other types of casing joints employed.

In San Joaquin County the average domestic well casing is six inches and the average irrigation well is twelve inches in diameter. Wells larger than sixteen inches in diameter are usually industrial or municipal wells. Shallow domestic wells, two and four inches in diameter, are common in the Delta Area. A few windmills, used for stock watering, also have casings of these small diameters.

Well casings are of uniform size except in the deeper gravel packed wells where the diameter of casing is normally reduced with increasing depth.

Although materials such as cast iron, copper, plastic, and concrete are more resistant to corrosion than steel, their application as well casing is limited to use in shallow wells. Approximately 50 percent of the casings used in wells in San Joaquin County are perforated in place after the well is

drilled. This fact is due to the great number of wells drilled by the cable tool method. When drilling wells by the cable tool method, the casing is driven simultaneously with the drilling. After the drilling is completed and the location of the water-bearing formations have been determined, the casing is perforated. One common method of in-place perforation of the casing employs the Mills Knife. The knife is expanded against the inside of the casing and contracted after the perforation is made in the water-bearing zone. The process is repeated several times in each zone. When drilling by the rotary method, the sides of the well are prevented from caving by the drilling mud--a colloidal clay solution. The casing is installed at the completion of drilling after the water-bearing strata have been determined. Therefore, casing with milled or torch cut perforations is normally used in rotary drilled wells.

The use of well screens as a section of the casing, rather than pre- or post-perforated casing is increasing, especially in the Delta Area. These screens are made of stainless steel,making them less susceptible to corrosion. The size of the screen openings is chosen in accordance with the grain size of the water-bearing formations. If the openings are too large, "sanding in" will result, and if they are too small, the well will have a poor yield due to low inflow.

Sealing Off Strata

Not many drillers attempted to seal off undesirable strata once the casing has been perforated in a zone of saline water. One apparently successful seal has been accomplished on a California Water Service Company well in Stockton. It was determined that one particular zone was responsible for a continuing degradation in the quality of water in the well. The sealing in this gravel packed well consisted of inserting a metal liner inside the casing opposite the perforations at the poor quality zone.

In case of the cable tool method, strata bearing undesirable quality water are excluded by driving unperforated casing through these sections of the well. The undesirable water may be detected by sampling from each water-bearing stratum as the drilling progresses. Frequently, the driller may know from previous experience which strata in a given area contain poor quality waters. At the completion of drilling the casing is perforated opposite only those strata containing good quality water.

In case of the rotary drilling method it is extremely difficult to detect the quality of water in the different strata during the drilling process. However, most of the large industrial, municipal, and irrigation wells drilled by this method are electric logged at the completion of drilling, before the well is cased and packed with gravel. When electric logging is used to supplement the conventional driller's log, it is possible to distinguish between the strata bearing poor or good quality water. After the driller determined the zones of poor quality water, the undesirable strata can be sealed off by placing cement grout, puddled clay, or concrete instead of gravel into the annular space opposite these formations.

Well Development

About half of the wells drilled in San Joaquin County are developed by the well drillers. The rest are developed during use of the newly constructed wells. The purpose of developing a well is to increase the permeability of the material opposite the perforations. The increased permeability results in a greater yield with less drawdown in the well. Development consists of some method of loosening the fine material in the water-bearing zones, drawing the fines into the well shaft, and removing them from the well. A variety of methods can be utilized, including surging of the water in the well by alternately starting and stopping the pump, surging by use of a plunger or compressed air, introducing dry ice, or pumping at an excessive rate for

several hours or sometimes days. The latter is the most common method in San Joaquin County.

Sanitary Features

Out of the 497 wells inspected during the construction survey only 179 had a surface seal to prevent leakage of surface and soil water into the annular space of the well casing. The remaining 318 wells had no surface seal. Seals were noted between the casing and the platform, between the pump base and the platform, and between the casing and the pump column.

Well vents were found on only 22 inspected wells. On four of these vents a protective screen, to prevent the entrance of insects, was used. A hole in the pump base leading into the well or a pipe connected to the casing, serving the purpose of measuring or disinfecting the well, was observed on 197 wells. Only 25 percent of these measuring holes were capped to prevent the entrance of insects or surface water.

There was evidence of lubricant leaking into one-third of all wells inspected. Thirty-three percent had a shelter designed to accommodate the well and pump. Another two percent were enclosed in other type buildings such as garages. Fifty percent of the shelter floors were of concrete, thirteen percent of wood, and the remaining thirty-seven percent were of dirt.

Pump platforms of some type were found at eighty-three percent of the wells. Platforms made of concrete were by far the most common, numbering 304, or sixty-one percent of all wells inspected during the survey. Other types of platforms encountered were: wood - fifteen percent; metal - six percent; brick - one percent. A well pit to accommodate the pump was noted in 25 instances, all in the east side of the county.

About half of the drillers interviewed indicated that they disinfect wells for domestic use. Clorox or chlorinated lime are the disinfectants presently used by the drillers.

Sealing and Destruction of Wells [1/]

About half the well drillers working in San Joaquin County have experience in sealing wells. Usually, when some attempt is made to properly destroy a well, it is because a new well is being drilled close to the abandoned well. Although the practice is not proper, many drillers will then allow the cuttings from the new well to drain into the old one.

Unless the well owner is familiar with the harmful effects that an abandoned well can have on ground water supplies, he is usually unwilling to pay someone to properly destroy his well. He may wish to save his old well and use it as a drainage well, garbage pit, septic tank drain, or similar purpose.

A few wells have been sealed with cement grout by drillers for the California Water Service Company, in Stockton, and for the federal government, at the Tracy Army Depot.

Seismic Exploration Practices

Recent ground water analyses from wells in the vicinity of Stockton, Tracy, and French Camp showed an increase in chloride concentrations. The cause of these high chlorides was not known and County officials thought the increase could be attributed to intensive seismic exploration activities near French Camp, or a migration of saline waters through the "barrier". At the request of San Joaquin County officials a study of the practice of drilling and abandoning seismic drill holes was included in this investigation.

The purpose of seismic exploration is to determine the geology beneath the earth's surface. This is accomplished by (1) drilling a series of holes approximately 15-30 feet below the water level, usually spaced about

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1/ For definitions of terms, see Appendix B.

400 feet apart; (2) setting an explosive charge in each drill hole; (3) installing electrically connected geophones along the line of drill holes; and (4) detonating the explosive charges.

The energy from the explosion is transmitted into the ground. After an interval this energy, having been reflected from one or more subsurface discontinuities, returns to the ground surface. Upon return to the ground surface, the energy activates a mechanical-electrical transducer (geophone). The output of the detector is amplified and recorded by a seismograph which produces a record called a seismogram. From this recording, the underlying geology may be interpreted and also the probability of finding gas and oil. The seismic exploration in an area always precedes any actual drilling for gas or oil in that locality.

All drilling and production of oil and gas in California is closely scrutinized by the State Division of Oil and Gas, whose chief function is to protect the State's oil and gas resources and to insure that saline waters, characteristic of the deep oil and gas formations, are not allowed to penetrate the good quality aquifers located relatively close to the ground surface. These functions are accomplished by inspecting the work of oil and gas companies to insure that their drilling and abandonment of oil and gas wells are carried out in accordance with prescribed procedures consistent with good practices. The Division of Oil and Gas does not have any jurisdiction over the operations of seismic exploration companies.

Some seismic exploration companies are independently owned and receive all their work through subcontract with the oil and gas companies. Other seismic exploration organizations are affiliated with an oil or gas company and do all the seismic exploration work for that particular company.

During the field investigation of seismic exploration practices it was found that the depth of drill holes in which the explosive charges were placed ranged from 15-30 feet below the water table. It was stated by a representative of an oil company that there is no need to drill deeper as the best results are obtained with the charges just below the water table. Plates 6 and 7, which show depth to water in wells throughout San Joaquin County, give an indication of the probable depth of seismic exploration holes drilled in each area. These holes are usually drilled with a four-inch rotary bit.

The charge placed in each hole varies from 1/8 of a pound to 200 pounds of TNT. The size is primarily dependent upon the consolidation and type of material through which the energy from the explosion must travel. The more consolidated the material is, the smaller the charge required to do the job. In San Joaquin County, the charges are generally less than ten pounds.

Methods employed in backfilling of drill holes at the completion of testing vary slightly with each company. Some oil companies specify to the subcontracting seismic exploration company the method to be used in backfilling holes while others leave it to the discretion of the seismic exploration company. One company used the following procedure:

(1) Backfill the hole with drill cuttings to a depth above the Water Table.

(2) Set a Dupree shot hole bridge slightly above the water table.

(3) Place a mixture of cement, water, and gravel on top of the bridge to form a concrete plug.

(4) Backfill the remainder of the hole to within three feet of ground surface with drill cuttings.

(5) Insert a precast tapered concrete plug three feet below ground surface.

(6) Backfill the remaining three feet with drill cuttings or adjacent soil.

Another company eliminated steps (2) and (5) but inserted a precast tapered concrete plug 15 feet below ground level. A third company followed the listed procedure with the exception of step (5). All companies felt that the method of backfilling they employed was adequate to prevent any movement of water through these holes.

The oil or gas company holding the lease on the land is liable for any damages caused by an improperly abandoned drill hole; therefore, they are usually conscientious in seeing that these drill holes are properly abandoned. One seismic exploration company employee did state, however, that if it is the desire of a land owner to leave a drill hole open for use as a drainage hole or small well, his request was usually complied with.

Reports of water wells collapsing due to the explosions set off during seismic exploration, or during actual drilling and development of gas wells, were investigated by this department and in two instances by personnel from the Division of Oil and Gas. In one instance the following facts were revealed:

(1) Two dry gas wells were drilled in the area at distances of about 500 and 800 feet from the water well.

(2) The gas wells were drilled and abandoned in accordance with prescribed methods set forth by the Division of Oil and Gas and were inspected by their personnel.

(3) In five instances it was impossible to determine whether seismic exploration activity contributed to the failure of wells. Reasons for the doubts concerning the evidence against the seismic

exploration companies were: Some of the wells were not in use at the time of seismic exploration activities; the collapsed condition was not discovered for months after the completion of seismic exploration work in the area; the owner himself did not think the seismic exploration activity caused the damage; and in two instances the stories were conflicting and the circumstances concerning the collapsed wells were suspicious.

(4) In the two cases concerning the drilling of gas wells in the vicinity of water wells that subsequently collapsed or supposedly became damaged, no evidence was found that the activities of the gas companies caused damage to these wells.

(5) It does not appear that the prevailing seismic exploration practices present a source of degradation to ground water supplies so long as drill holes are four inches in diameter, not deeper than 30 feet below ground water levels, and are adequately backfilled.

(6) Data regarding the name of the seismic exploration company, name of company for whom work is being done, location of seismic drill holes, dates of exploration activity, depth and size of charge, and method of backfilling is presently not required for explorations conducted on privately owned land.

Data relating to all seismic exploration activity within the county would be valuable for determining if damage to wells and ground water supplies actually did result from these operations. The following may be of assistance to the county in evaluating effects of seismic exploration, frequency of wells collapsing, and degradation of ground water supplies in the vicinity of seismic exploration activities:

(1) Submission of data to a responsible county agency on the location of test holes, size of explosive charges used, date of shooting, name of company doing seismic exploration, and name of company for whom work was being done.

(2) Proper abandonment of test holes by a method equivalent or better than the one outlined on Page 45.

(3) Limitation of seismic exploration activity to a distance of not less than 300 feet from any existing well.

(4) No holes will be left open unless properly cased and condition corresponds with standards set for water well construction.

(5) Submission of data to the same responsible agency on the date of completion, log of test holes, method of abandonment, description of damages, if any, and condition of test holes if left open.

CHAPTER IV

RECOMMENDED STANDARDS FOR WATER WELL CONSTRUCTION AND DESTRUCTION OF WELLS

Although most drillers in San Joaquin County are aware of what constitutes a properly constructed well, they are seldom able to drill such a well. A lack of knowledge and apathy on the part of the general public regarding proper well construction makes it mandatory for drillers to quote prices which do not include such items as concrete platforms, proper sealing from surface waters, chlorination, etc. These "extras" are not included because the driller knows that the contract will generally go to the driller quoting the lowest price.

It is hoped that the following recommended water well construction and sealing standards will be incorporated into a County ordinance. These standards conform with the recommendations contained in Bulletin No. 74, "Water Well Standards: State of California", July 1962. Enforcement of this ordinance should protect the quality of ground water in San Joaquin County from further impairment due to conditions resulting from improperly constructed or improperly destroyed wells. The standards should apply to wells already in existence as well as those to be constructed in the future. This is especially true of the standards pertaining to sealing of wells no longer in use of maintained by the owner. Wells not considered to be usable must be properly destroyed.

This chapter is separated into two parts: General Standards, that apply to all areas of the County as minimum requirements, and Supplemental Standards that are considered necessary in portions of San Joaquin County where water quality problems exist.

General Standards

The following general standards are applicable to all methods of well construction. It should be noted that the local authorities may wish to adopt more stringent requirements than those presented in this report.

Well Location

In selecting a potential well site it is important that the well be located above flooding zones and up the ground water gradient from sources of contamination.

Many variables, such as soil porosity, ground water gradient, etc., are involved in the determination of the safe distance of a well from potential sources of contamination. The following distances, on the basis of past experience and general knowledge, are considered safe under most conditions.

Source of Contamination	Minimum Distance To Well
Sewer, watertight septic tank, or pit privy	50 feet
Sewage disposal field (subsurface), barnyards, or fenced areas for livestock	100 feet
Cesspool or seepage pit	150 feet

Special characteristics of certain areas may require that the local authorities increase these minimum distances to prevent possible contamination of the well water.

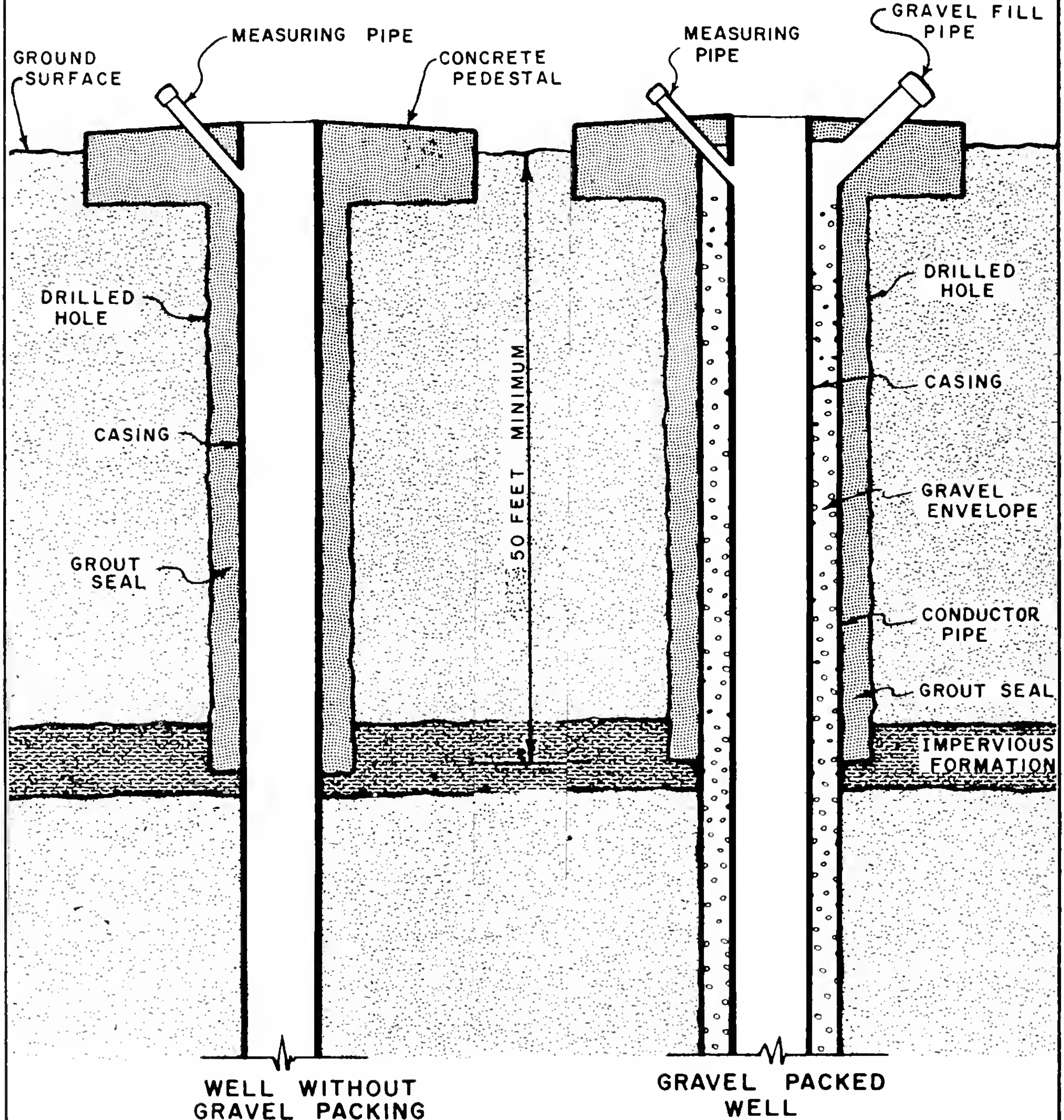
Sanitary Requirements

The following recommendations are primarily concerned with protection of ground water against contamination by surface and shallow subsurface waters, or by entrance of foreign material into the well.

Annular Space. The annular space between the well, or the conductor casing, and the wall of the drilled hole shall be filled with cement grout or other sealing material approved by local authorities and set into an impervious formation overlying the uppermost aquifer. The thickness of the seal shall be at least one and one-half inches and extend to a minimum depth of 50 feet. Where an impervious formation does not exist within 50 feet, the seal shall be extended to the depth specified by local authorities. The sealing material shall be applied, if possible, in one continuous operation and begin at the deepest point to be sealed, progressing upwards, completing the operation at the surface. Annular seals are illustrated in Figure 1.

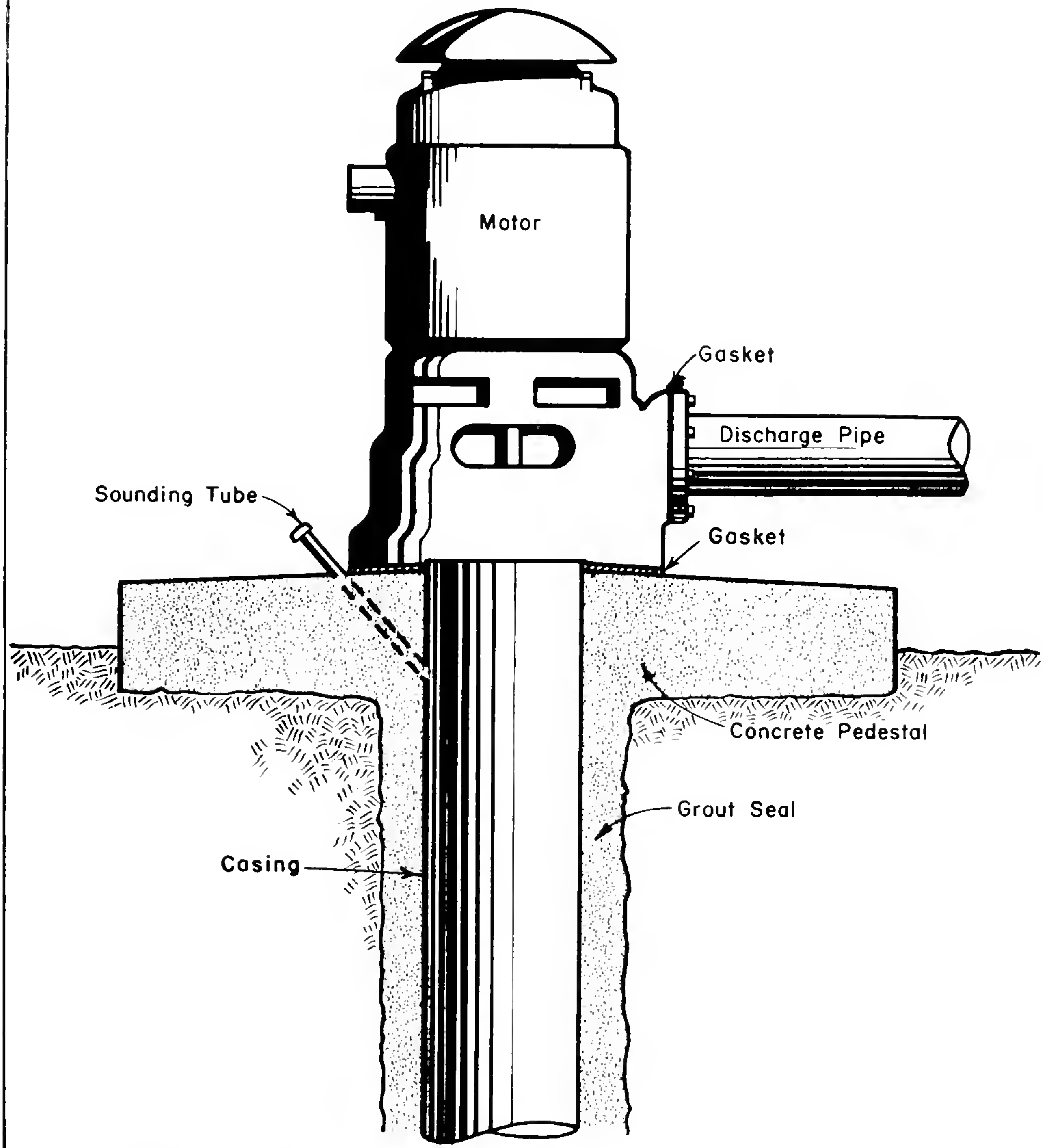
Pedestal. A monolithically poured concrete pedestal shall be constructed, in a manner similar to that shown on Figure 2, on compacted earth around the top of the well, regardless of whether the pump is mounted over the well, is offset from the casing, or is of the submersible type. The pedestal shall be at least six inches thick at its extreme outer edge and slope away from the casing.

Surface Seals. The opening in the top of the well casing shall be provided with a watertight seal. When the pump is installed directly over the casing, a watertight seal can be obtained by sealing the pump base to the pump pedestal or well cover, sealing the opening between the casing and the column pipe, or setting the pump to secure a watertight seal between the pump base and the rim of the casing. All holes in the pump base that open into the well shall be sealed. When the pump is offset from the well, or when the dimensions of the pump base are smaller than the diameter of the casing, or when a submersible pump is used, the opening between the well casing and any pipes or cables entering the well shall be closed by a watertight seal. Pump



NOT TO SCALE

TYPICAL ANNULAR SANITARY SEALS



NOT TO SCALE

TYPICAL CONCRETE PEDESTAL

discharge piping shall be located above the ground where possible; and in the event of a below-ground discharge, there shall be a watertight seal between the discharge pipe and the well casing.

Access and Air Vent Pipes. Access openings into well casings shall be protected against entrance of surface waters or foreign matter by installation of watertight caps or downturned "U" bends equipped with screens. In gravel-packed wells a gravel fill pipe may be installed through the surface seal but the fill pipe shall be made watertight at the ground surface.

Well Pits. The use of well pits shall be avoided whenever possible. Well pits shall not be constructed to a depth below the recorded high water table. If a pit is necessary, the lining shall be constructed of monolithic, reinforced concrete, watertight in all respects. The top of the pit shall be sloped away from the well casing. Provision shall be made for natural drainage of water from the pit, or sump pump installed where gravity drainage is not possible.

Drilling Mud and Water. Mud and water used in drilling shall be free from contamination and come from acceptable sources.

Gravel. Gravel used in gravel-packed wells shall come from clean sources and shall be washed before being placed in the well. If the source of gravel is questionable, the gravel shall be thoroughly washed and chlorinated before being placed in the well.

Disinfection. All wells, except those used solely for agriculture, shall be disinfected with a chlorine compound following initial installation or subsequent repairs to the well or pump, before the well is placed in service. Sufficient chlorine compound shall be added to the standing water in the well to give a residual of 50 ppm free chlorine. After the disinfectant has been placed in the well, the pump shall be started and stopped several times to

thoroughly mix the disinfectant with the water in the well. The pump shall then be stopped and not operated for a period of 24 hours. After 24 hours the pumping shall be resumed until the odor or taste of chlorine is no longer detectable.

The quantities of some standard chlorine compounds required to provide 50 ppm of free chlorine for each 100 feet of water-filled casing are presented in Table 9.

TABLE 9

Diameter of Casing in Inches	70% HTH, Perchloron, etc. (Dry Wt.)	(25%) Chloride of Lime (Dry Wt.)	(5%) Purex, Chlorox, etc. (Liquid Measure)
2	1/4 ounce	1/2 ounce	2 ounces
4	1 ounce	2 ounces	9 ounces
6	2 ounces	4 ounces	20 ounces
8	3 ounces	7 ounces	2 1/8 pints
10	4 ounces	11 ounces	3 1/2 pints
12	6 ounces	1 pound	5 pints
16	10 ounces	1 3/4 pounds	1 gallon
20	1 pound	3 pounds	1 2/3 gallons
24	1 1/2 pounds	4 pounds	2 1/3 gallons

Note: It is suggested that when wells to be treated are of unknown depth or volume, at least one pound of 70% available chlorine or two gallons of household bleach such as Chlorox or Purex (5% chlorine) should be added in lieu of the quantities shown in the above table.

Casing

Well casing shall be of sufficient strength, toughness, and thickness to resist all forces and stresses imposed during and after installation.

Casing Material. Steel casing equal to or exceeding the well thickness given in Table 10 should withstand the stresses imposed upon a casing.

TABLE 10

SUGGESTED MINIMUM WALL THICKNESS FOR STEEL
WELL CASING

Single Casing

Depth of Casing in Feet	Diameter in Inches										
	2-6	8	10	12	14	16	18	20	22	24	30
0-100	12	12	10	10	8	8	1/4	1/4	1/4	1/4	5/16
100-200	12	10	10	8	8	3/16	1/4	1/4	1/4	1/4	5/16
200-300	10	10	8	8	1/4	1/4	1/4	1/4	5/16	5/16	5/16
300-400	10	8	8	3/16	1/4	1/4	1/4	5/16	5/16	5/16	3/8
400-600	10	8	3/16	1/4	1/4	5/16	5/16	5/16	5/16	3/8	3/8
600-800	3/16	3/16	1/4	1/4	5/16	5/16	3/8	3/8	7/16	7/16	7/16
Over 800	1/4	1/4	1/4	5/16	5/16	3/8	3/8	7/16	7/16	1/2	1/2

Figures above diagonal are United States Standards Gage Numbers.

Figures below diagonal are thickness in inches.

Double Casing

Depth of Casing in Feet	Diameter in Inches								
	10	12	14	16	18	20	22	24	30
0-100	12	12	12	12	10	10	10	10	8
100-200	12	12	12	10	10	10	10	8	8
200-300	12	12	10	10	10	10	8	8	8
300-400	12	12	10	10	10	8	8	8	8
400-600	10	10	10	10	8	8	8	8	8
600-800	10	10	10	8	8	8	8	8	8
Over 800	10	8	8	8	8	8	8	8	8

Figures are United States Standards Gage Numbers.

Damaged or defective material, or wood shall not be used as casing. Concrete casing poured in place shall be adequately reinforced. Single layer brick walls shall be surrounded by concrete at least six inches thick. Except for perforations, all casings shall be watertight.

Conductor Pipe. In gravel packed wells a conductor pipe or casing shall be installed between the casing and the wall of the drilled hole to a minimum depth of 50 feet below the ground surface so as to contain the gravel and to prevent the entrance of undesirable water. A watertight cover shall be installed between the conductor pipe and the well casing at the ground surface.

Installation of Casing. Damage to casing sections and joints during placement is to be avoided. The casing joints must be structurally sound, and except for perforated areas, watertight. Where the diameter of the casing is reduced, the joint between the different diameter casings shall be made watertight.

Perforations. The perforations should not unduly weaken, tear, or deform the casing. The casing of deep wells shall not be perforated within 50 feet of the ground surface.

Sealing Off Strata

When a well is perforated in several strata, one of which has water of marginal quality, the stratum shall be sealed off to prevent entrance of the water into the well and comingling of waters in the annular space. The sealing material shall be impervious and placed in a proper manner to insure a satisfactory seal.

In the cable tool method, driving unperforated casing through the stratum will, in most instances, provide an adequate seal. Cement grout or other suitable material shall be applied in the interval to be sealed, to fill the

annular space between the casing and the wall, in wells drilled by methods leaving larger annular space. The sealing material shall be placed from the bottom to the top of the annular space to be sealed.

Well Development

Developing, redeveloping, or conditioning of a well shall be accomplished by methods that will not cause damage to the well. Care shall be exercised to prevent occurrence of adverse subsurface conditions that may destroy barriers to the vertical movement, thus, permitting exchange of water between aquifers. The latter recommendation is particularly important when the quality of water in one of the aquifers is poor.

Water Quality Sampling

In order to determine the mineral quality of ground water and its suitability for the intended uses, it is recommended that the water in the wells be sampled immediately following construction and development.

Samples shall be collected after the well has been pumped long enough to remove standing water from the well casing. This will insure that the samples are representative of the formations. A chemically clean container shall be used. Rinsing several times with the water to be sampled is, in most cases, sufficient. Generally, one-half gallon of sample is adequate.

It may also be advisable to take samples during construction, especially if the quality of water in some aquifers is questionable.

Analyses, appropriate for the intended uses, shall be made.

Water Well Drillers' Report

Submission of a report upon completion of a well or of work on an existing well is required by law (Section 7076 of the California Water Code). These reports are a source of geologic and hydrologic data and are extremely valuable in studies of the underground reservoirs of the State.

Destruction of Wells

Abandoned wells may provide a pathway for the exchange of ground water from one aquifer to another. When a well no longer serves a useful purpose, or has fallen into such a state of disuse and disrepair that it may become a source of impairment to ground water quality, it shall be properly sealed and destroyed in order to prevent such impairment.

Description of Abandoned Well. A well is considered "abandoned" when it has not been used for a period of one year, unless the owner declares his intention to use the well again. As evidence of his intention to use the well again, the owner shall maintain the well in such a way that:

(1) The well has no defects which will facilitate the impairment of quality of water in the well or in the developed water-bearing formations;

(2) The well is covered with an appropriate locked cap;

(3) The well is marked so that it can be clearly seen;

(4) The area surrounding the well is kept clear of brush or debris.

If the pump has been removed for repair or replacement, the well shall not be considered "abandoned." During the repair period, the well shall be adequately covered to prevent injury to people and to prevent the entrance of undesirable water or foreign matter.

Wells used in the investigation or management of ground water basins by federal, state, or local agencies or other appropriate engineering

organizations, even though they are temporarily out of use, are not considered "abandoned" so long as they are maintained. However, such wells shall be covered with an appropriate locked cap when measurements are not being made.

Sealing Procedure. To correctly seal an abandoned well, the well shall first be inspected and a comparison made with the original log to insure the absence of obstructions. If a well has an obstruction or is filled in with sand or other materials, these shall first be removed to the original depth. The casing shall be ripped or perforated so that when the sealing material is applied, the annular space as well as the casing will be filled with cement grout or other suitable impervious material. In sealing gravel packed wells, the sealing material shall be applied within the casing, completely filling it, and forced out under pressure into the gravel envelope.

Supplemental Standards

In addition to the minimum requirements presented as general standards, supplemental well construction and sealing standards are considered necessary in portions of San Joaquin County where water quality problems exist. Plates 8, 9, 10, and 11 show the approximate areas and magnitudes of these problems. The Eastern Area, Tracy Area, Delta Area, and Stockton Area are discussed in turn.

To obtain additional data necessary to clarify the geologic, hydrologic, and other factors relating to well standards in particular problem areas, this investigation was intensified in the vicinity of the Stockton, French Camp, and Tracy Areas. Interviews with representatives from County facilities, well owners, well drillers, and other sources of information confirmed the complex ground water situation existing in these areas. In order to determine if there were water-bearing formations which could yield water of

suitable quality and could, by proper sealing, be isolated from poor quality underlying or overlying formations, a formation testing program was initiated to obtain water from different formations without dilution from the adjacent zones. Information on this formation testing program is presented in the separately bound Appendix E of this report. The result of this work indicated that data presently available are not sufficient to completely define or delineate the problems, nor are they sufficient to pinpoint specific aquifers or zones in these areas as being responsible for the problems.

The "San Joaquin County Ground Water Investigation", approved by this Department to start during the 1964-65 fiscal year, will provide additional information on the geologic and hydrologic conditions that exist in the problem areas of San Joaquin County.

Standards for Specific Water Quality Problem Areas

Based on the existing data and available information, supplemental standards were developed. In many cases, the occurrence of poor quality water is a natural phenomenon and even the presence of an improperly constructed or abandoned well would not adversely affect ground water in these or adjacent areas. The following supplemental standards should be instrumental in preserving and protecting ground water quality in problem areas by providing higher standards of well construction than are generally required throughout the County.

Delta Area

Chloride, hardness, and to a lesser extent boron, are problems in parts of the Delta Area. Most fresh ground water in this area is contained in small pockets, or lenses, surrounded by saline water. The supplemental standards recommended for this area are intended to prevent spreading of the problems as a result of construction practices which permit interchange of waters from

different aquifers. The deltaic sediments of the area were deposited in marine or brackish water. Saline waters are found at all depths in these deltaic deposits. The fresh water usually extends to a depth of less than 150 feet.

Depth Limitations. Fresh water in the area usually extends to a depth of less than 150 feet; therefore, drilling of deeper wells should be avoided to eliminate the possibility of interchange of water from poor quality, deep zones.

Determination of Poor Quality Water-Bearing Zones. Gravel packed wells in this area should be constructed on the basis of an electric log or some other means of identification of mineral quality within the penetrated zones. Cable tool wells should be constructed on the basis of an adequate water quality sampling program suitable to identify poor quality water-bearing zones. Casings should not be perforated in these poor quality zones and the gravel envelope should not permit vertical movement and interchange of waters.

Tracy Area

Boron, hardness, and moderately high to high chlorides are problems in parts of the Tracy Area. Water of better than average quality is available at various locations but the quantity is inadequate, due to the relatively low specific capacity of the fresh water-bearing sediments in many parts of the area. Throughout much of this area the principal fresh water-bearing aquifer, located around 400-500 feet, is overlain by the Corcoran Clay, a member of the Tulare Formation. Marginal zones of the Corcoran Clay have lenses of sand, silt, and gravel interfingered with the clay bed. The Corcoran Clay separates the fresh water-bearing deposits of the Lower Tulare Formation from the upper portions of this formation, which generally contain poor quality water at a depth interval of around 100-200 feet. The principal fresh water-bearing zone is underlain by formations older than the Tulare Formation. These are of marine origin and are not fresh water-bearing. Both the shallow and deep formations

containing poor quality water should be sealed off in accordance with the following supplemental standards.

Depth Limitation. The principal fresh water-bearing aquifer in the area usually extends to a depth of about 500 feet; therefore, drilling of deeper wells should be avoided to eliminate the possibility of interchange of waters from poor quality, deep zones.

Perforation of Deep Wells. Deep wells should not be perforated into the aquifers above the Corcoran Clay, located at about 100-200 feet, in order to prevent intrusion of the generally poor or marginal quality water into the principal fresh water-bearing zone.

Construction of Shallow Wells. Shallow wells (50-60 feet deep) may provide water of suitable quality for some beneficial uses. These shallow wells should not extend into the poor quality zone above the Corcoran Clay.

Determination of Poor Quality Water-Bearing Zones. Gravel packed wells in this area should be constructed on the basis of an electric log, or some other means of identification of mineral quality, within the penetrated zones. Cable tool wells should be constructed on the basis of an adequate water quality sampling program suitable for identifying poor quality water-bearing zones. Casing should not be perforated in these poor quality zones and the gravel envelope should not permit vertical movement and interchange of waters.

Location and Sealing of Improperly Constructed Wells. A large number of gravel packed wells exist throughout the Tracy Area. Some of the gravel packed wells may permit the interchange of poor quality waters. These wells should be located and the poor quality zones sealed off.

Stockton Area

A "barrier", that so far has apparently prevented lateral migration of saline water eastward from the Delta, exists within the Stockton Area and extends north and south into adjacent areas. Additional information is needed concerning the exact location and nature of the "barrier" before its effects can be definitely stated; however, it is important to implement the following supplemental standards throughout the "barrier" zone to prevent possible damage to the usable ground water found mainly in the unconsolidated Alluvium, Victor, and Laguna Formations east of the "barrier".

Specific Standards for the "Barrier" Zone. Drilling of wells in the "barrier" zone is not advisable; however, if wells are drilled, poor quality zones should be determined and properly sealed. Determination of poor quality zones should be made in accordance with the specific standards listed for gravel packed and cable tool wells in the Delta and Tracy Areas. Sealing off strata of poor quality water should be performed in accordance with the general standards.

Eastern Area

Although the quality of ground water in the Eastern Area of San Joaquin County is generally excellent for all beneficial uses, the serious overdraft conditions that are apparent east and southeast of Stockton could pose a threat to the quality of this supply. It appears that the steepening of the ground water gradient as yet has not been sufficient to introduce quality problems; however, well construction practices that permit indiscriminate interchange of waters from various aquifers may, at some future date, aggravate the conditions if the lateral migration or poor quality water occurs. The portions of the Eastern Area where conditions are most likely to become aggravated are the "barrier" zone, the areas of heavy overdraft, and areas where water quality

problems appear sporadically. There are no specific standards presently recommended for the Eastern Area except for the "barrier" zone north and south of Stockton.

Specific Standards for the "Barrier" Zone. The standards listed for the "barrier" zone of the Stockton Area should be applied within the "barrier" zone of the Eastern Area as well.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

As a result of the investigation leading to the preparation of this report, the following conclusions and recommendations are made:

Conclusions

(1) The survey of water well construction and sealing practices, combined with the sanitary survey and ground water quality studies in San Joaquin County, indicate that in many instances present methods of well construction and sealing are not adequate to protect the quality of ground water from degradation.

(2) With the exception of such entities as the California Water Service Company most abandoned wells are not adequately sealed to prevent comingling of water from both good and poor water aquifers.

(3) Ground water in formations above the Valley Springs Formation in the Eastern Area and above the Mehrten Formation in the Stockton Area, with the exception of some sections adjacent to the Delta Area, is generally good to excellent in mineral quality and satisfactory for most beneficial uses.

(4) Despite lowering of ground water levels, no noticable general degradation of the fresh water or fresh water aquifers has been observed east of the "barrier" beneath the Stockton or Eastern Area. The fact that lateral migration of saline water across the "barrier" has not been clearly observed, does not mean that some migration may not have already occurred.

(5) Ground water of good mineral quality in the Delta Area is generally found in small sand lenses less than 150 feet below the ground surface. These lenses, or pockets, of fresh water are surrounded by highly saline water. Due to the nonuniform geology in this area, it is impossible to predict the quality of the ground water before drilling a water well.

(6) Ground water in the Tracy Area is often high in boron and should be analyzed before being applied to boron sensitive crops. Boron in ground water is an extensive areal problem, with concentrations generally increasing toward the foothills. There are indications that ground water in the lower aquifer, beneath the Corcoran Clay between Tracy and the San Joaquin River extending south to Linne Road, is presently being degraded by comingling with the overlying saline water in the upper aquifer. Large gravel envelope wells, some of which are improperly abandoned, with perforations in both aquifers may be contributing to the degradation.

(7) Most water well drillers are cognizant of all the features a completed well should have, but due to the competitive nature of their business, they are unable to include all necessary features unless the customer recognizes their importance and is willing to pay the extra cost.

(8) In order to prevent continued degradation of ground water through improperly constructed and abandoned water wells in San Joaquin County, adequate water well construction and sealing standards must be employed. In addition, existing water wells causing water quality degradation must be corrected to conform to such standards.

Recommendations

It is recommended that:

(1) San Joaquin County adopt and enforce, at the earliest possible date, adequate water well construction and sealing standards for the protection of ground water quality.

(2) The information presented in this bulletin be used as a guide in developing such standards.

(3) San Joaquin County adopt and enforce standards for sealing and destroying a water well no longer in use or ever intended to be used again.

(4) Responsible agencies in San Joaquin County begin investigative work leading to the identification and correction of existing improperly constructed and abandoned water wells. This work should commence initially in the Eastern Area adjacent to the Delta Area.

(5) San Joaquin County formulate regulations governing seismic exploration activities.

Because of the importance of protecting water quality it is requested that officials of San Joaquin County keep the Central Valley Regional Water Pollution Control Board and this department informed of progress in the implementation of these recommendations.

APPENDIX A

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BIBLIOGRAPHY

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APPENDIX B

DEFINITION OF TERMS

DEFINITION OF TERMS

The following terms used in this report are defined as follows:

Abandoned Well - a well whose original purpose and use has been permanently discontinued or which is in such a state of disrepair that it cannot be used for its original purpose.

Active Well - an operating water well.

Annular Space - the space between two well casings or a well casing and the drilled hole.

Aquiclude - a formation or part of a formation which, although porous and capable of absorbing water slowly, will not transmit it rapidly enough to furnish an appreciable supply for wells or springs.

Aquifer - a formation or part of a formation sufficiently permeable to transmit an appreciable supply of water to wells or springs.

Aquifuge - a rock which contains no interconnected openings and therefore neither absorbs or transmits water.

Aquitard - a formation or part of a formation which retards water movement, but is permeable enough to permit appreciable, slow movement -- permeability somewhat greater than that of an aquiclude; characteristically overlies a semi-confined ground water body.

Capped Well - a water well from which the pump has been removed, and a permanent or locked cap installed on top of the casing.

Casing - a tubular retaining structure, generally metal or concrete, installed in the excavated hole to maintain the well opening.

Cement Grout - a fluid mixture of cement and water of a consistency that can be forced through a pipe and placed as required. Various additives, such as sand, bentonite, and hydrated lime, are included in the mixture to meet certain requirements. For example, sand is added when a considerable volume of grout is needed.

Clay - a predominately fine-grained material (having a large proportion of grains less tnan 0.005 mm in diameter) which has high plasticity and very low permeability.

Conductor Pipe or Casing - a tubular retaining structure installed in the drilled hole surrounding the inner casing. It is located generally in the upper portion of a well.

Cone of Depression - the water surface in the water-bearing formation within the area of influence of a pumping well. It resembles the shape of a cone with its apex at the pumping level in the well.

Confined Ground Water - a body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with overlying ground water except at the intake. Confined ground water moves in conduits under pressure due to the difference in head between the intake and discharge areas of the confined water body.

Connate Water - water entrapped in the interstices of a sedimentary rock at the time it was deposited. These waters may be fresh, brackish, or saline in character. Because of the dynamic geologic and hydrologic conditions in California, this definition has been altered in practice to apply to water in older formations, even though the water in these formations may have changed in quality since the rock was originally deposited.

Contamination - defined in Section 13005 of the California Water Code: "An impairment of the quality of the waters of the State by sewage or industrial waste to a degree which creates an actual hazard to public health through poisoning or through the spread of disease...." Jurisdiction over matters regarding contamination rests with the State Department of Public Health and local health officers.

Degradation - impairment in the quality of water due to causes other than disposal of sewage and industrial waste.

Destroyed Well - a well that has been properly plugged or sealed, filled, and capped so that it will not produce water nor act as a conduit for the movement of water.

Deterioration - an impairment, generally used in connection with water quality.

Drawdown - lowering of water level caused by pumping. It is measured for a given quantity of water pumped during a specified period, or after the pumping level has become constant.

Drilled Well - a well for which the hole is generally excavated by mechanical means such as the rotary or cable tool methods.

Driller's Mud - a fluid composed of water and clay (either native clay or in combination with commercial clays) used in the drilling (primarily rotary) operation to remove cuttings from the hole, to clean and cool the bit, to reduce friction between the drill stem and the sides of the hole, to plaster the sides of the hole, and to prevent collapse of the drilled hole. Such fluids range from relatively clear water to carefully prepared mixtures of special purpose compounds.

Formation - a fairly widespread group of rocks or unconsolidated materials having characteristics of origin, age, and composition sufficiently distinctive to differentiate the group from other units. The formation is the fundamental geologic unit.

Free Ground Water - water in interconnected interstices in the zone of saturation not overlain by impervious materials, and moving under control of the water table slope.

Gravel Packed Well - a well in which gravel is placed in the annular space to increase the effective diameter and to prevent the entrance of fine-grained sediments.

Ground Water - subsurface water in the zone of saturation.

Ground Water Basin - an area underlain by permeable materials. The permeable materials must be water-bearing, i.e., generally capable of furnishing a water supply to wells of moderately heavy draft (100 gpm or more). The basin includes both the surface area and the underlying permeable materials.

Hydraulic Gradient - a profile showing the static level of water at all points. Hydraulic gradient of ground water records the head consumed by friction of flow between any selected points on the profile. The water table registers the hydraulic gradients of free ground water, and the pressure surface those of confined water.

Impairment - a change in quality of water making it less suitable for any or all beneficial uses.

Impermeable Stratum - a formation or part of a formation having a composition that does not permit water to move through it perceptibly under the head differences ordinarily found in the zone of saturation.

Inactive or Standby Well - a well not operating but capable of being made an operating well with a minimum of effort.

Industrial Waste - defined in Section 13005 of the California Water Code: "Any and all liquid or solid water substance, not sewage, from any producing, manufacturing or processing operation of whatever nature."

Liner - a section of pipe smaller in diameter, used to seal openings in the existing casing and installed permanently within a well.

Overdraft - continuing decrease in the amount of ground water in storage over a long time period, under a particular set of physical conditions, affecting the supply, use, and disposal of water in the ground water basin.

Packer - a device that plugs or seals the well at a desired level when placed inside the casing.

Parts Per Million (ppm) - one weight of solute per million weights of solution.

Perforations - a series of openings in a well casing, made either before or after installation, to permit the entrance of water into the well.

Percolation - a type of laminar flow occuring in interconnected openings of saturated granular material under hydraulic gradients commonly developed underground.

Permeability - the capacity of material to transmit water, measured by the quantity passing through a unit cross section in a unit time under 100 percent hydraulic gradient. Degree of permeability depends upon the size and shape of the pores, and the size, shape, and extent of their interconnections.

Pollution - defined in Section 13005 of the California Water Code: "An impairment of the quality of the waters of the State by sewage or industrial waste to a degree which does not create an actual hazard to the public health but which does adversely and unreasonably affect such waters for domestic, industrial, agricultural, navigational, recreational, or other beneficial use, or which does adversely and unreasonably affect the ocean waters and bays of the State devoted to public recreation." Regional Water Pollution Control Boards are responsible for prevention and abatement of pollution.

Pressure Grouting - a method of forcing impervious grout into specific portions of a well, such as the annular space, for sealing purposes.

Puddled Clay - clay or a mixture of clay and sand, kneaded or worked when wet, thus making it impervious.

Sealed Well - a well in which one or more aquifers have been sealed off so as to prevent the entrance of water from the sealed aquifer (s).

Sewage - defined in Section 13005 of the California Water Code: "Any and all waste substance, liquid or solid, associated with human habitation, or which contains or may be contaminated with human or animal excreta or excrement, offal, or any feculent matter." As used in this report, sewage is included as part of the waste waters carried by community sewer systems.

Specific Capacity - the number of gallons per minute of water produced by a pumping well per foot of drawdown.

Specific Yield - the ratio of the volume of water which rock or soil will yield by gravity to its own volume; it is customarily expressed in percent.

Standing Level - the water level in any nonpumping well. Within the area of influence of pumping wells the standing level registers one point on the cone of depression. Outside the area of influence the term is equivalent to static level.

Static Level - the water level in a nonpumping well outside the area of influence of any pumping well. This level registers one point on the water table in a free ground water well or one point on the pressure surface in a confined ground water well.

Subsurface Water - all water occuring below the ground surface.

Water Table - in pervious granular material the water table is the upper surface of the body of free water which completely fills all openings in material sufficiently pervious to permit percolation.

APPENDIX C

WELL NUMBERING SYSTEM

Well Numbering System

The state well numbering system used in this report is based on township, range, and section subdivision of the Public Land Survey. This system is used in all ground water investigations and for numbering all wells for which data are published or filed by the Department of Water Resources. The number of a well, assigned in accordance with this system, is referred to as the State Well Number.

Under the system, each section is divided into 40-acre tracts lettered as follows:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Note that I and O are omitted in the grid above.

Wells are numbered within each 40-acre tract according to the chronological sequence in which they have been assigned State Well Numbers. For example, a well which has the number 1N/6E-17K1, would be in Township 1 North, Range 6 East, Section 17, Mount Diable Base and Meridian, and would be further designated as the first well assigned a State Well Number in tract K. Well numbers are referenced to the Humboldt Base and Meridian (H), the Mount Diablo Base and Meridian (M), or the San Bernardino Base and Meridian (S).

APPENDIX D

WATER QUALITY CRITERIA

WATER QUALITY CRITERIA

Criteria presented in the following sections are utilized in evaluating the mineral quality of water relative to existing or anticipated beneficial uses. It should be noted that these criteria are merely guides to the appraisal of water quality. Unless the limiting value concerns a toxic constituent in water used for drinking, water with constituents exceeding one or more of these limiting values need not be eliminated from consideration as a source of supply. However, other sources of better quality water should be investigated.

These criteria are based on experience and research by numerous entities and provide a yardstick for present evaluation of the mineral quality of waters.

Domestic and Municipal Water Supply

The drinking water standards most widely accepted in the United States are those proposed by the United States Public Health Service. The limiting concentrations of mineral constituents for drinking water are divided into two groups:

1. Mandatory Limits which constitute grounds for rejections of the water supply. These limits are specified to protect the consumer from increased buildup of toxic constituents which are likely to prove lethal in time.

2. Non-Mandatory but Recommended Limits which are applicable when excess toxic chemical substances are present, but their concentrations are not likely to be lethal. When the quality of a water supply exceeds these limits, consideration should be given to a more suitable supply.

Table 1

UNITED STATES PUBLIC HEALTH SERVICE
DRINKING WATER STANDARDS
1962

Chemical Substance	Limit in ppm (In mg/l)
Mandatory	
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Hexavalent) (Cr^{+6})	0.05
Cyanide (CN)	0.02
Fluoride (F)	1.6 *
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	
Non-Mandatory but Recommended	
Alkyl Benzene Sulfonate (ABS)	0.5
Arsenic (As)	0.01
Chloride (Cl)	250.0
Copper (Cu)	1.0
Carbon Chloroform Extract (CCE)	0.2
Cyanide (CN)	0.01
Fluoride (F)	1.0 **
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate (NO_3)	45.0 ***
Phenols	0.001
Sulfate (SO_4)	250.0
Total Dissolved Solids	500.0
Zinc (Zn)	5.0

* The mandatory limit of 1.6 ppm fluoride is based on an annual average maximum daily air temperature of 74.0° at Stockton; it is twice the recommended optimum control limit.

** The recommended limit of 1.0 ppm fluoride is based on an annual maximum daily air temperature of 74.0° at Stockton; it is the recommended upper control limit.

*** In areas where nitrate content of the water is known to be in excess of the recommended concentration limit of 45 ppm, the public should be warned about the potential dangers of using the water for infant feeding.

The limiting concentrations of fluoride shown in Table 1 are applicable when fluoride is naturally present in drinking water.

Where fluoridation (supplementation of fluoride in drinking water) is practiced, the average fluoride concentration shall be kept within the following upper and lower control limits.

Annual average of maximum daily air temperatures (Based on temperature data obtained for a minimum of five years)	Recommended Control Limits Flouride Conc.in mg/1		
	Lower	Optimum	Upper
63.9 - 70.6	0.7	0.9	1.2
70.7 - 79.2	0.7	0.8	1.0
79.3 - 90.5	0.6	0.7	0.8

The California State Department of Public Health adopted more exacting standards for recommended concentrations of fluoride ion. These standards are presented in the following table.

LIMITS AND RANGE OF FLUORIDE ION CONCENTRATION IN DRINKING WATER AS DELIVERED TO THE CONSUMER

Mean Annual Temperature	Fluoride Ion Concentration - ppm*		
	Minimum	Range	Maximum
50°	0.9	0.9-1.2	1.5
60°	0.7	0.7-0.9	1.0
70°	0.4	0.4-0.6	0.7
62° (Stockton)	0.64	0.64-0.84	0.94

* For temperature values between those shown in the above table the fluoride ion concentration may be obtained by interpolation.

The temperature values in the preceding table are shown as mean annual temperature (62° at Stockton) and not as the annual average of maximum daily air temperatures (74° at Stockton).

In addition, the United States Public Health Service recently announced limits on concentrations of radioactivity in drinking water, as follows:

Constituent	Recommended Maximum Limits, Micromicrocuries per Liter
Radium ^{226}	3
Strontium ^{90}	10
Gross beta activity	1,000 *

* In the known absence of strontium^{90} and alpha emitters.

Interim standards for certain mineral constituents have been adopted by the California State Board of Public Health. Based on these standards, temporary permits may be issued for drinking water supplies failing to meet the United States Public Health Service Drinking Water Standards, provided the mineral constituents in the following table are not exceeded.

UPPER LIMITS OF TOTAL SOLIDS AND SELECTED MINERALS IN DRINKING WATER AS DELIVERED TO THE CONSUMER

	Permit	Temporary Permit
Total solids	500 (1000)*	1500 ppm
Sulfates (SO_4)	250 (500)	600 ppm
Chlorides (Cl)	250 (500)	600 ppm
Magnesium (Mg)	125 (125)	150 ppm

* Numbers in parentheses are maximum permissible, to be used only where no other more suitable water is available in sufficient quantity for use in the system.

Even though hardness of water is not included in the above standards, it is important in domestic and industrial uses. Excessive hardness in water used for domestic purposes causes increased consumption of soap and formation of scale in pipes and fixtures. Classification of hardness used by the State of California, Department of Water Resources is presented in Table 2.

Table 2

HARDNESS CLASSIFICATION OF WATER

Range of Hardness Expressed as $CaCO_3$ in ppm	Relative Classification
0-100	Soft
101-200	Moderately Hard
More than 200	Hard

Irrigation Water Supply

Criteria for mineral quality of irrigation water have been developed by the Regional Salinity Laboratories of the United States Department of Agriculture in cooperation with the University of California. Because of diverse climatological conditions and the variation in crops and soils in California, only general limits of quality for irrigation waters can be suggested. The department uses three broad classifications of irrigation waters as listed below:

Class 1 - Regarded as safe and suitable for most plants under most conditions of soil and climate.

Class 2 - Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher ranges of this class.

Class 3 - Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

Limiting concentrations of chemical constituents in irrigation water as classified above are shown in Table 3.

Table 3

QUALITATIVE CLASSIFICATION OF IRRIGATION WATER

Chemical Properties	Class 1 Excellent to Good	Class 2 Good to Injurious	Class 3 Injurious to Unsatisfactory
Total dissolved solids, in ppm	Less than 700	700 - 2000	More than 2000
Conductance, in micromhos at 25°C	Less than 1000	1000 - 3000	More than 3000
Chlorides, in ppm	Less than 175	175 - 350	More than 350
Sodium, in percent of base constituents	Less than 60	60 - 75	More than 75
Boron, in ppm	Less than 0.5	0.5 - 2.0	More than 2.0

These criteria have limitations in actual practice. In many instances, water of a given quality may be wholly unsuitable for irrigation under certain conditions of use, and yet be completely satisfactory under other circumstances. Soil permeability, drainage, temperature, humidity, rainfall, and other conditions can alter the response of a crop to a particular quality of water.

Industrial Water Supply

Water quality criteria for industrial water are as varied and diversified as industry itself. Food processing, beverage production, pulp and paper manufacturing, and textile industries have exacting requirements, while cooling or metallurgical operations permit the use of poor quality water. In general, where a water supply meets drinking water standards, it is satisfactory for industrial use, either directly or following a limited amount of polishing treatment by the industry.

APPENDIX E

FORMATION TESTING

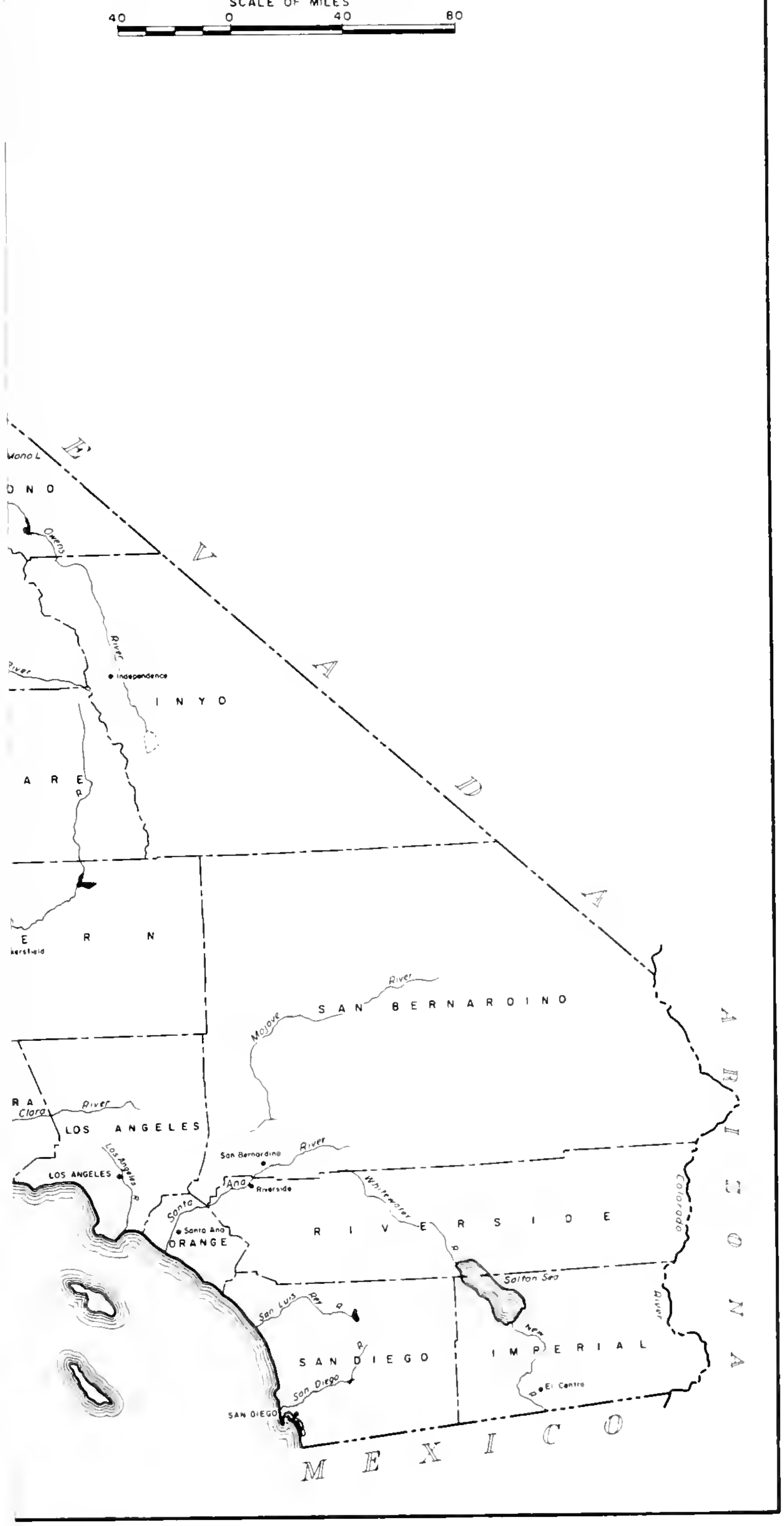
(This appendix bound separately)

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

OCATION OF AREA OF INVESTIGATION

SCALE OF MILES



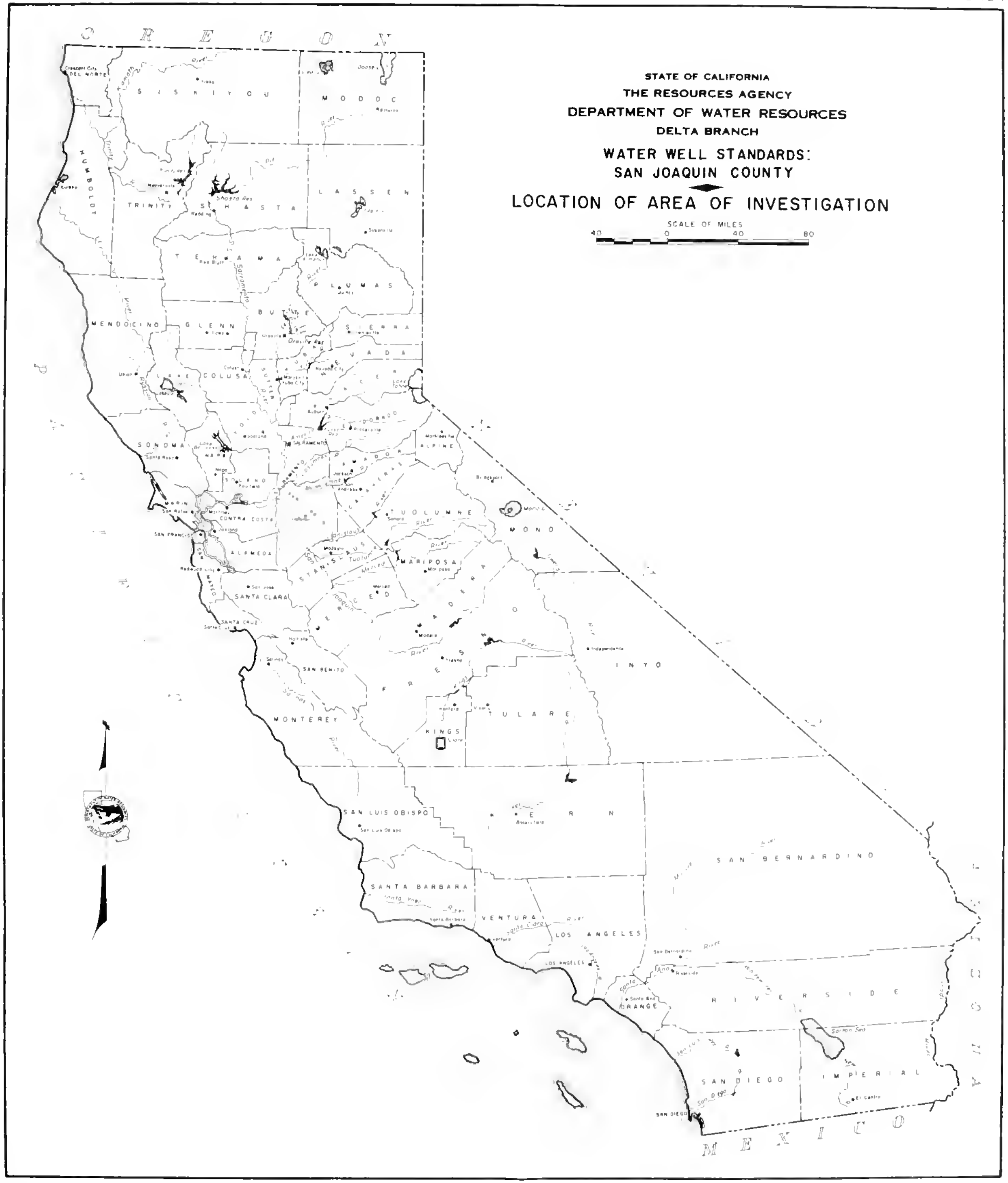
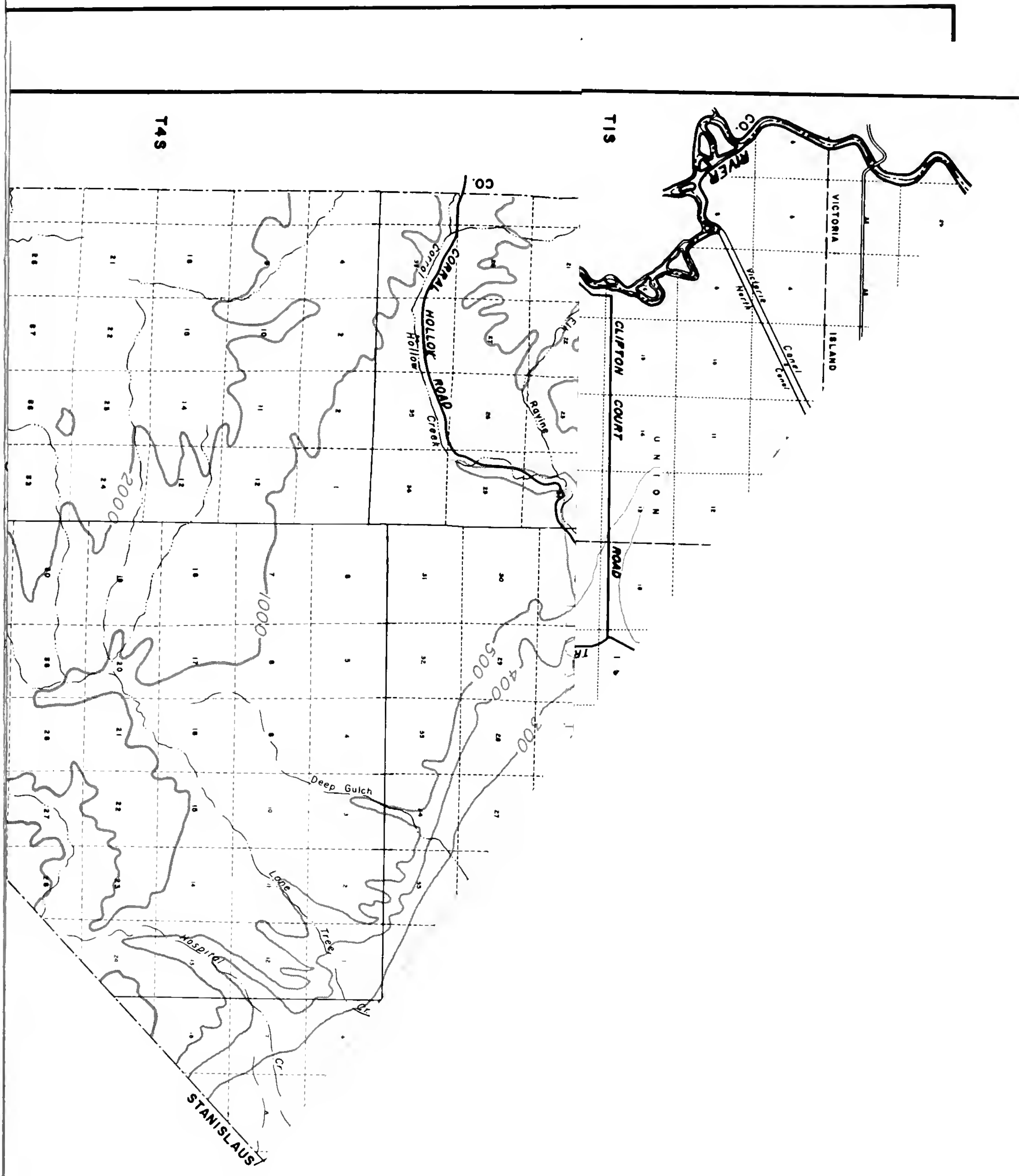
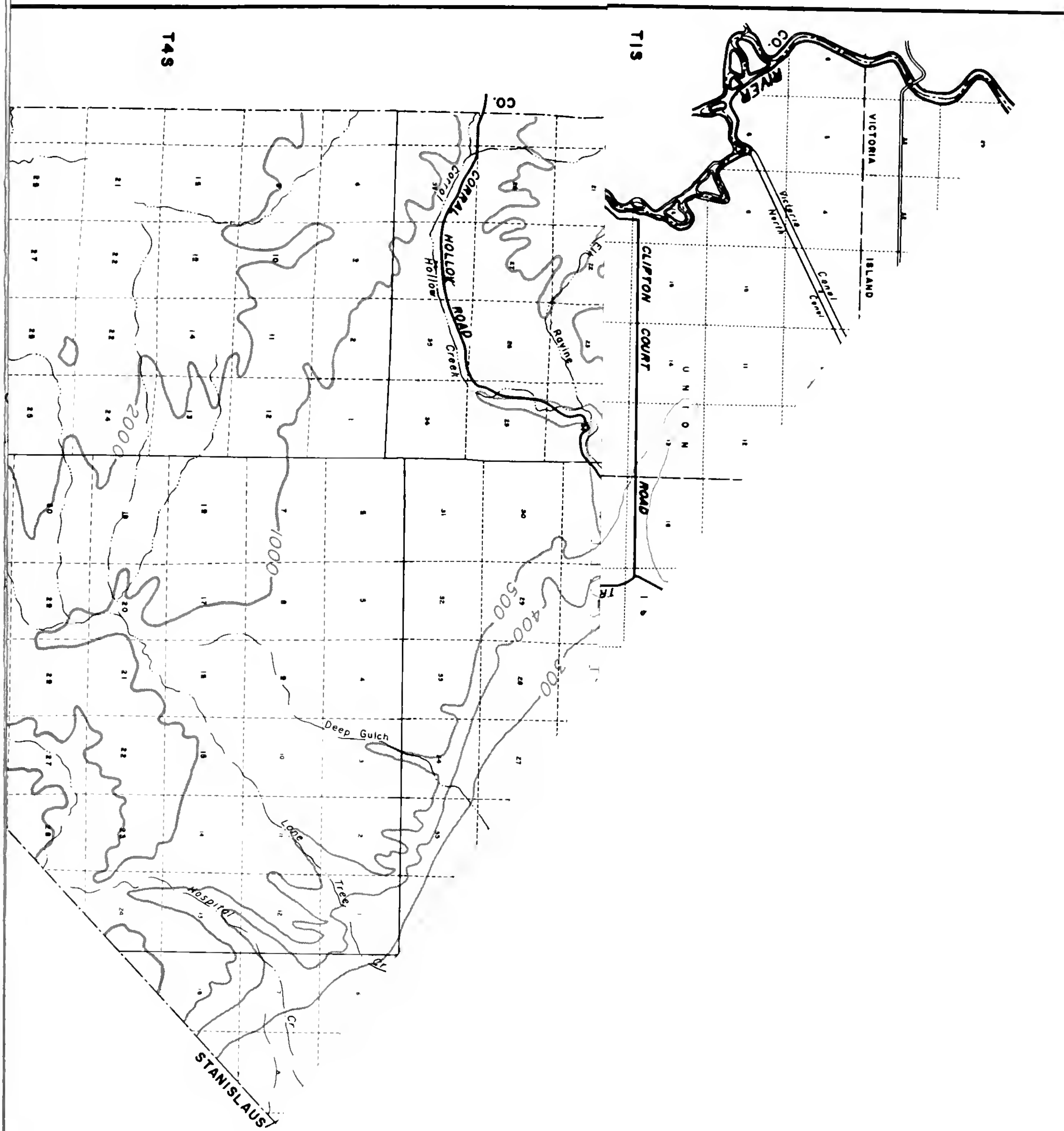

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
WATER WELL STANDARDS:
SAN JOAQUIN COUNTY
LOCATION OF AREA OF INVESTIGATION
SCALE OF MILES
40 0 40 80
OREGON
MEXICO
SISKIYOU
MODOC
DEL NORTE
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
LAKE
COLUSA
SUTTER
PLACER
YOLO
SONOMA
NAPA
SOLANO
SACRAMENTO
EL DORADO
ALPINE
AMADOR
CALAVERAS
MARIN
CONTRA COSTA
TUOLUMNE
MONO
SAN FRANCISCO
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
SAN BENITO
FRESNO
INYO
MONTEREY
KINGS
TULARE
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
Shasta Res
Oroville Res
Salton Sea

PLATE 2



T4S
T1S
CO.
CORRAL HOLLOW ROAD
Corral Hollow Creek
Ravine
CLIFTON COURT ROAD
UNION
RIVER
VICTORIA ISLAND
Victoria North Canal
2000
1000
500
400
300
Deep Gulch
Lone Tree
Hospital
Cr.
STANISLAUS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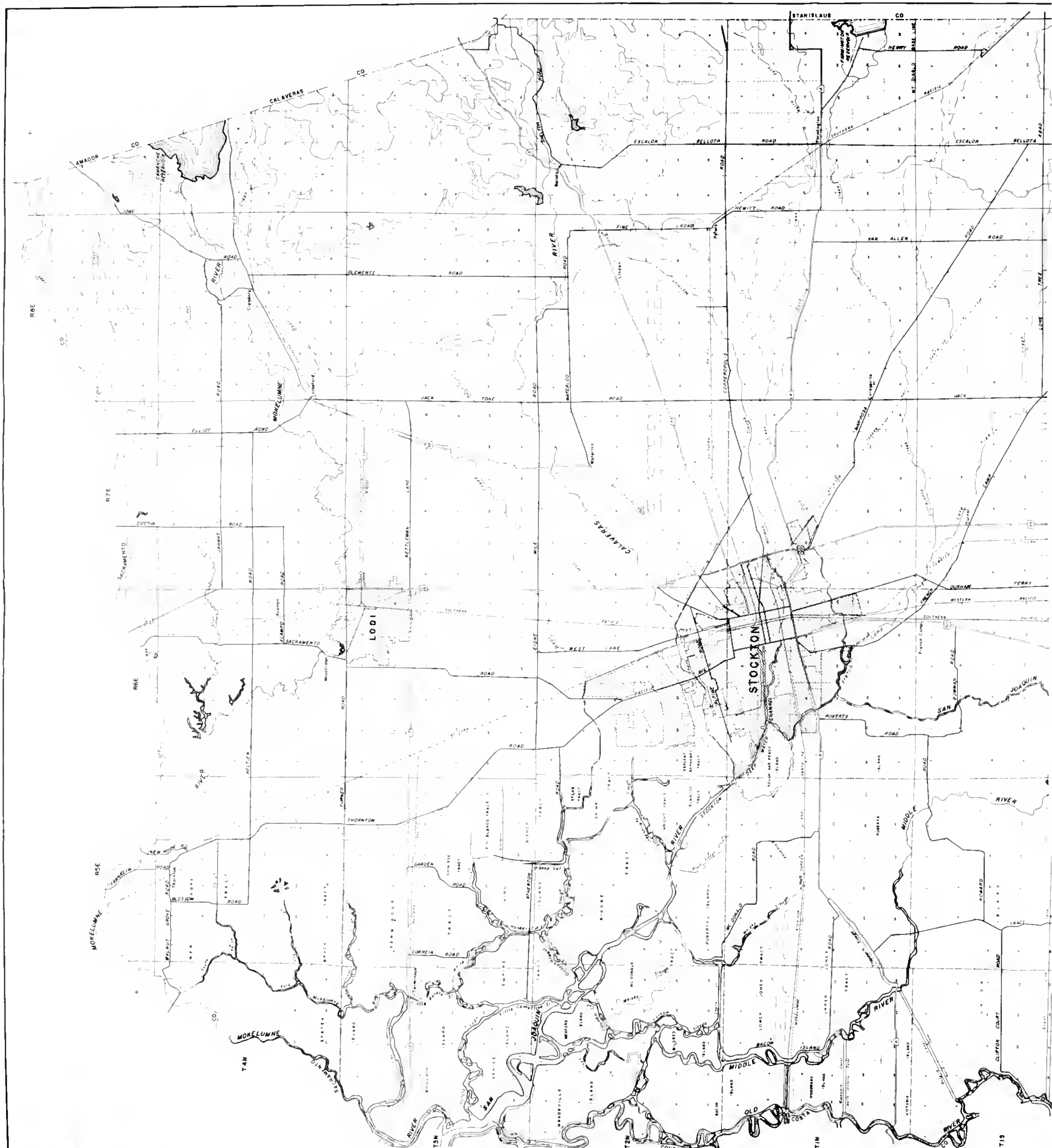
T1S
CO.
CORRAL HOLLOW ROAD
Corral Hollow Creek
CLIFTON COURT ROAD
RIVER
VICTORIA
ISLAND
Victoria North Canal
Canal
UNION
Ravine
Deep Gulch
Lone Tree Cr.
Hospital Cr.
STANISLAUS
2000
1000
500
400
300


STANISLAUS CO
CALAVERAS CO
AMADOR CO
CAMANCHE RESERVOIR
ESCALON BELLOTA ROAD
HEWITT ROAD
VAN ALLEN ROAD
FINE ROAD
CLEMENTS ROAD
JACK TONE ROAD
ELLIOT ROAD
DUSTIN ROAD
SACRAMENTO
LODI
STOCKTON
WEST LANE
CALAVERAS
COPPEROPOLIS
WATERLOO ROAD
EIGHT MILE ROAD
KETTLEMAN LANE
MOKELUMNE
RIVER
THORNTON
SAN JOAQUIN
MIDDLE
OLD
BACON ISLAND
ROBERTS
DURHAM FERRY
CONTRA COSTA
R8E
R7E
R6E
R5E
T4N
T3N
T2N
T1N
T1S

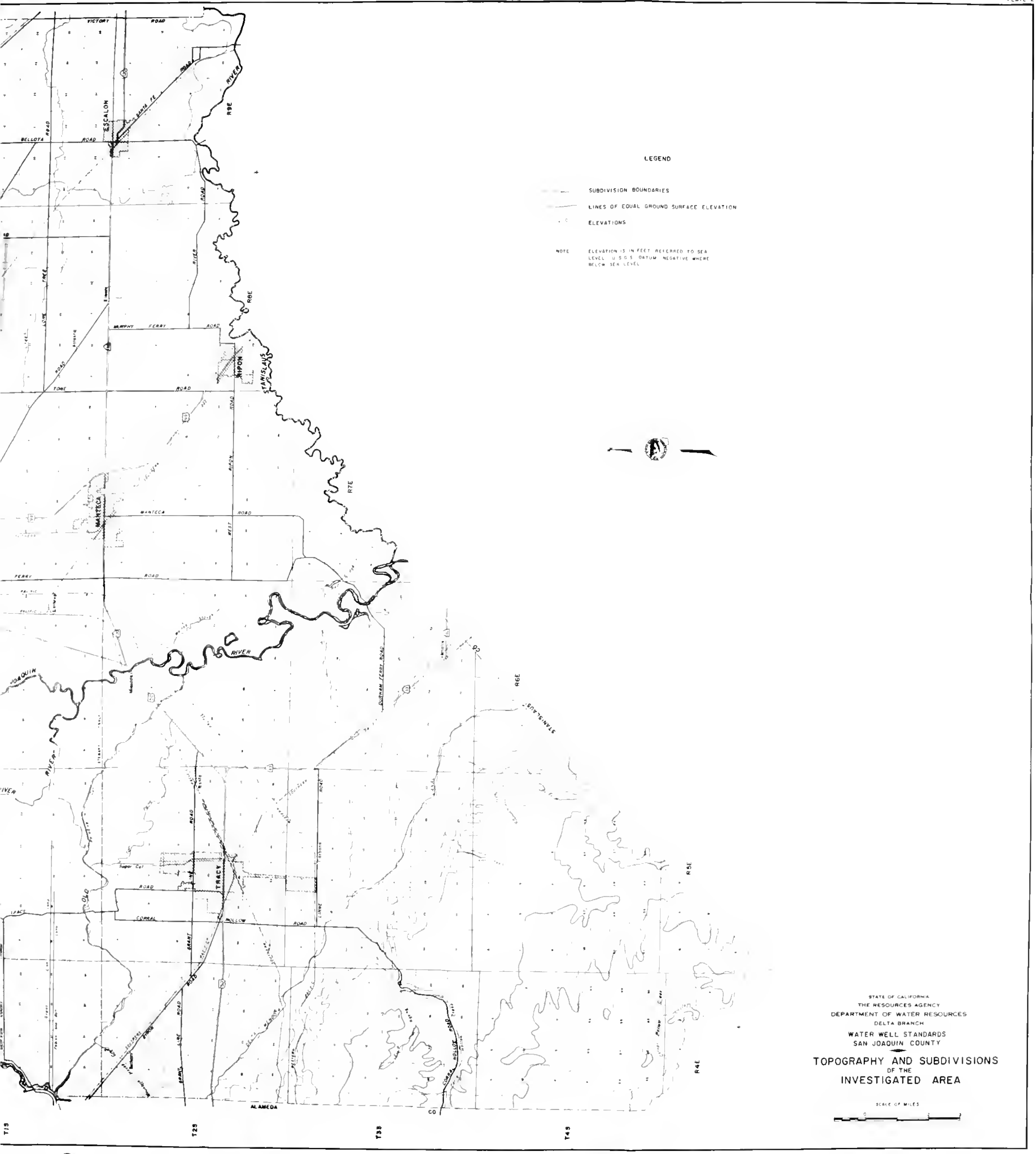
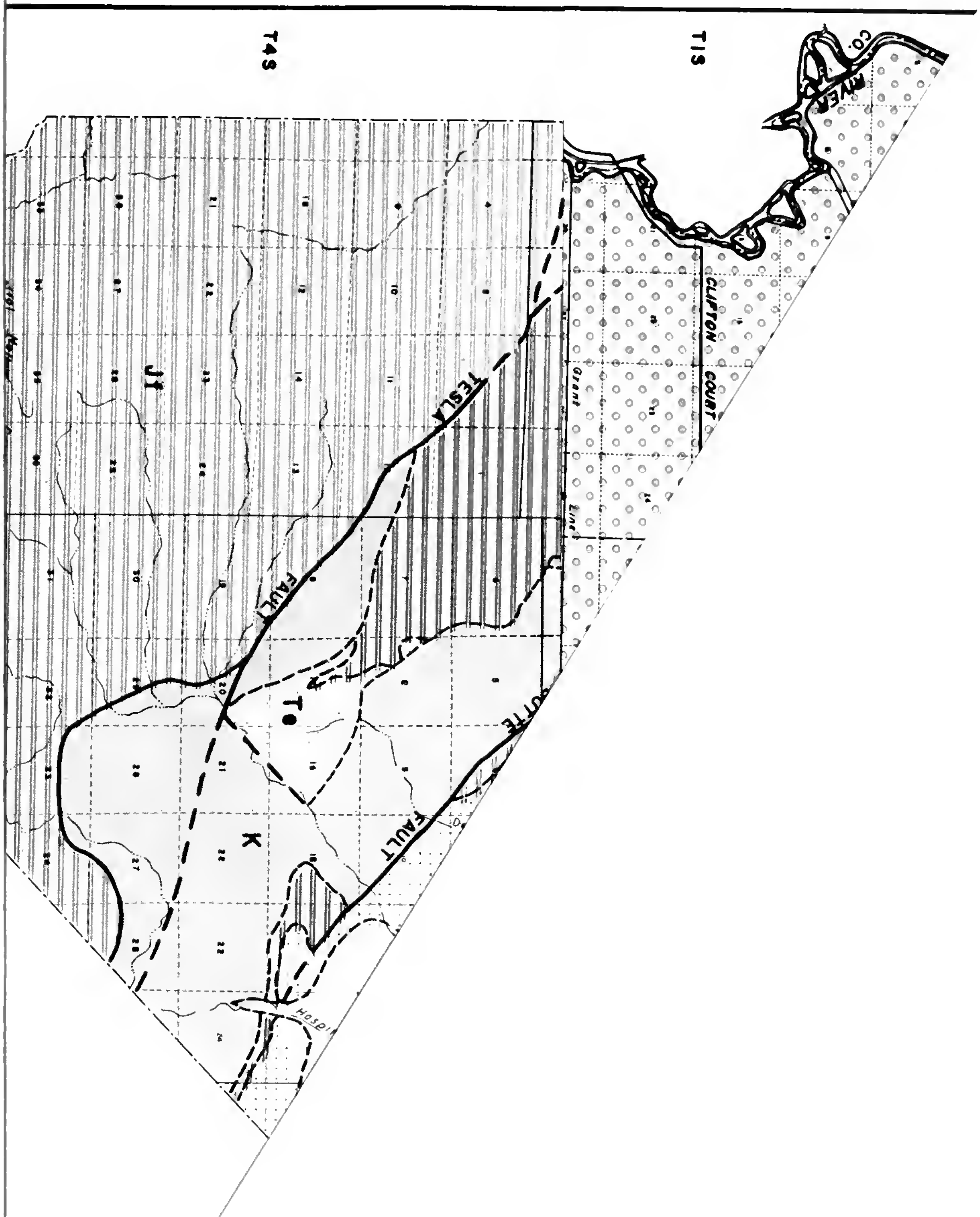
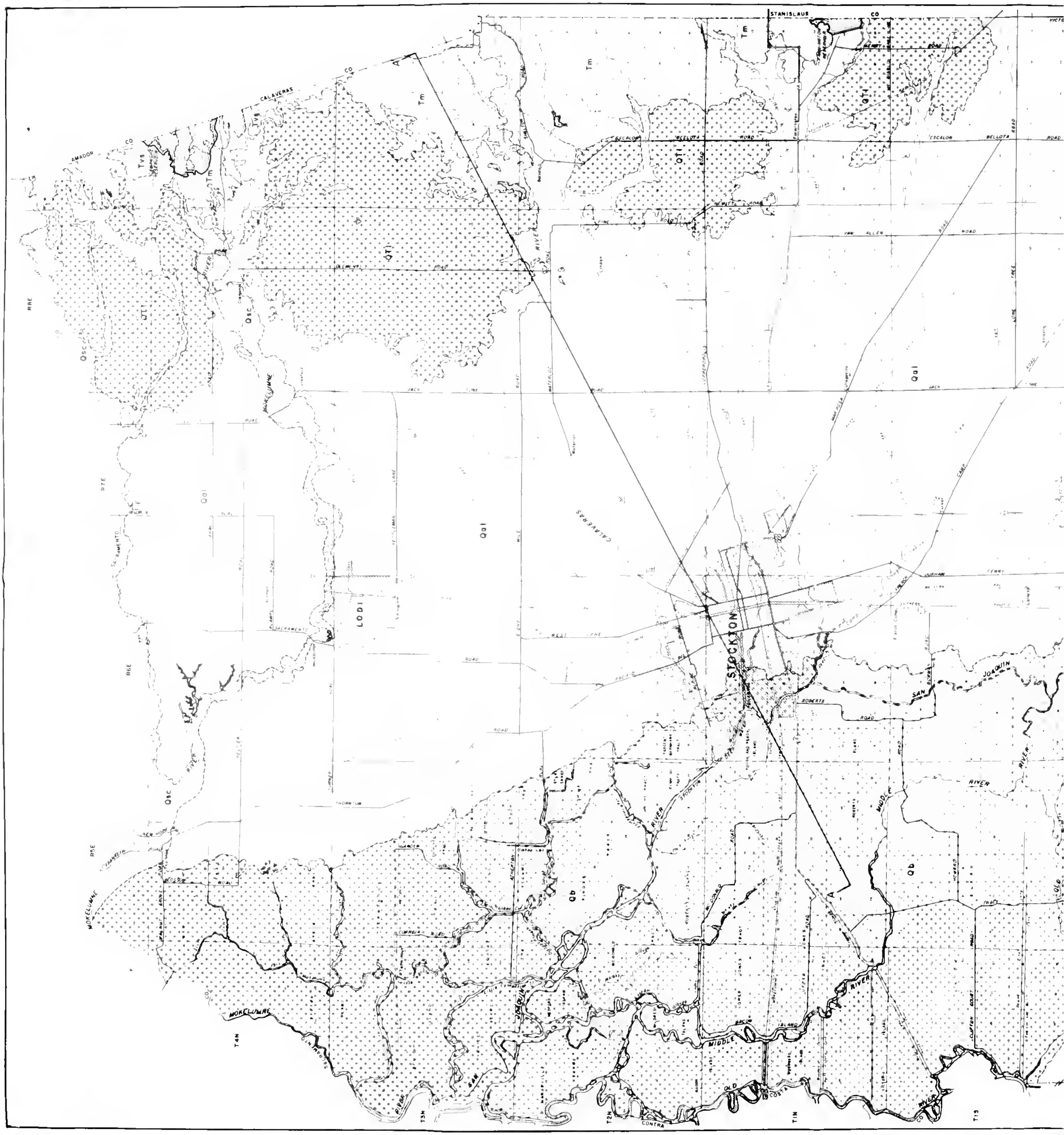
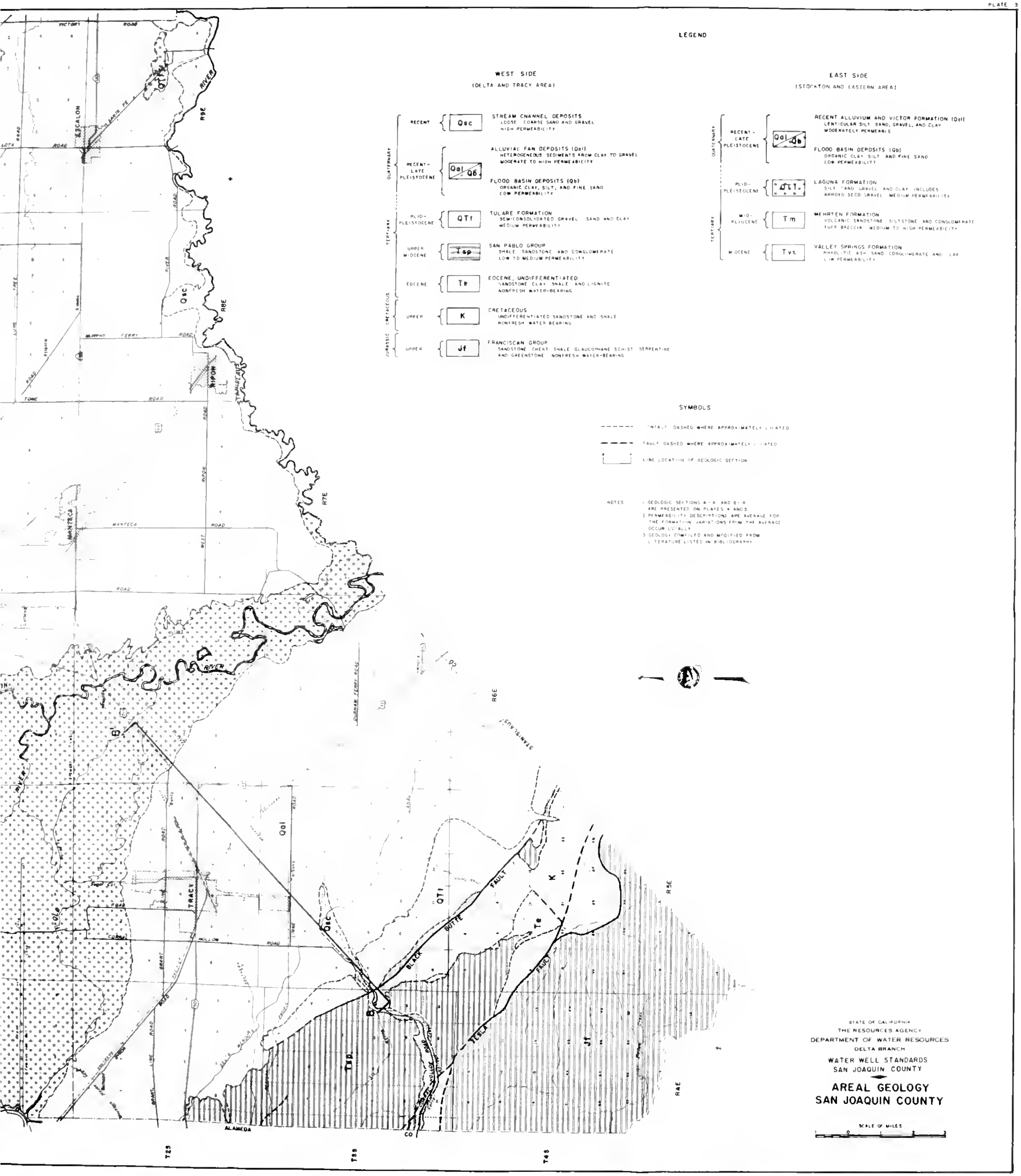

LEGEND
SUBDIVISION BOUNDARIES
LINES OF EQUAL GROUND SURFACE ELEVATION
ELEVATIONS
NOTE ELEVATION IS IN FEET REFERRED TO SEA LEVEL U.S.G.S. DATUM NEGATIVE WHERE BELOW SEA LEVEL
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
WATER WELL STANDARDS
SAN JOAQUIN COUNTY
TOPOGRAPHY AND SUBDIVISIONS
OF THE
INVESTIGATED AREA
SCALE OF MILES
VICTORY ROAD
BELLOTA ROAD
ESCALON
SANTA FE ROAD
RIVER
R9E
R8E
R7E
R6E
R5E
R4E
MURPHY FERRY ROAD
RIPON
STANISLAUS
TONE ROAD
RIPON ROAD
MANTECA
MANTECA ROAD
WEST ROAD
PERRY ROAD
RIVER
JOAQUIN
RIVER
DURHAM FERRY ROAD
OLD
TRACY
CORRAL HOLLOW ROAD
GRANT LINE ROAD
LINNE ROAD
ALAMEDA
CO
T1S
T2S
T3S
T4S

PLATE 3



T4S
T1S
TESLA
FAULT
FAULT
CLIFTON
COURT
RIVER
CO.
K
Grant
Line


STANISLAUS
CO
CALAVERAS
CO
AMADOR
CO
Tm
Tvs
QTl
Qsc
Qal
Qb
ESCALON
BELLOTA
ROAD
HEWITT
VAN ALLEN
JACK TONE
MOKELUMNE
RIVER
SACRAMENTO
CALAVERAS
LODI
STOCKTON
WEST LANE
PACIFIC
SAN JOAQUIN
ROBERTS
MIDDLE
OLD
RIVER
CONTRA COSTA
R8E
R7E
R6E
R5E
T4N
T3N
T2N
T1N
T1S
A


LEGEND
WEST SIDE
(DELTA AND TRACY AREA)
QUATERNARY
RECENT
Qsc
STREAM CHANNEL DEPOSITS
LOOSE COARSE SAND AND GRAVEL
HIGH PERMEABILITY
RECENT-LATE PLEISTOCENE
Qal / Qb
ALLUVIAL FAN DEPOSITS (Qal)
HETEROGENEOUS SEDIMENTS FROM CLAY TO GRAVEL
MODERATE TO HIGH PERMEABILITY
FLOOD BASIN DEPOSITS (Qb)
ORGANIC CLAY, SILT, AND FINE SAND
LOW PERMEABILITY
TERTIARY
PLIO-PLEISTOCENE
QTt
TULARE FORMATION
SEMICONSOLIDATED GRAVEL SAND AND CLAY
MEDIUM PERMEABILITY
UPPER MIOCENE
Tsp
SAN PABLO GROUP
SHALE SANDSTONE AND CONGLOMERATE
LOW TO MEDIUM PERMEABILITY
EOCENE
Te
EOCENE, UNDIFFERENTIATED
SANDSTONE CLAY SHALE AND LIGNITE
NONFRESH WATER-BEARING
CRETACEOUS
UPPER
K
CRETACEOUS
UNDIFFERENTIATED SANDSTONE AND SHALE
NONFRESH WATER BEARING
JURASSIC
UPPER
Jf
FRANCISCAN GROUP
SANDSTONE CHERT SHALE GLAUCOPHANE SCHIST SERPENTINE
AND GREENSTONE NONFRESH WATER-BEARING
EAST SIDE
(STOCKTON AND EASTERN AREA)
QUATERNARY
RECENT-LATE PLEISTOCENE
Qal / Qb
RECENT ALLUVIUM AND VICTOR FORMATION (Qal)
LENTICULAR SILT SAND, GRAVEL, AND CLAY
MODERATELY PERMEABLE
FLOOD BASIN DEPOSITS (Qb)
ORGANIC CLAY SILT AND FINE SAND
LOW PERMEABILITY
TERTIARY
PLIO-PLEISTOCENE
QTl
LAGUNA FORMATION
SILT SAND GRAVEL AND CLAY INCLUDES
ARROYO SECO GRAVEL MEDIUM PERMEABILITY
MIO-PLIOCENE
Tm
MEHRTEN FORMATION
VOLCANIC SANDSTONE SILTSTONE AND CONGLOMERATE
TUFF BRECCIA MEDIUM TO HIGH PERMEABILITY
MIOCENE
Tvs
VALLEY SPRINGS FORMATION
RHYOLITIC ASH SAND CONGLOMERATE AND CLAY
LOW PERMEABILITY
SYMBOLS
CONTACT DASHED WHERE APPROXIMATELY LOCATED
FAULT DASHED WHERE APPROXIMATELY LOCATED
LINE LOCATION OF GEOLOGIC SECTION
NOTES
1 GEOLOGIC SECTIONS A-A AND B-B ARE PRESENTED ON PLATES 4 AND 5
2 PERMEABILITY DESCRIPTIONS ARE AVERAGE FOR THE FORMATION VARIATIONS FROM THE AVERAGE OCCUR LOCALLY
3 GEOLOGY COMPILED AND MODIFIED FROM LITERATURE LISTED IN BIBLIOGRAPHY
ESCALON
RIPON
MANTECA
TRACY
VICTORY ROAD
SANTA FE
RIVER
TOMB ROAD
MANTECA ROAD
CORRAL HOLLOW ROAD
ALAMEDA
BLACK BUTTE FAULT
TESLA FAULT
STANISLAUS
DURHAM FERRY ROAD
R8E
R7E
R6E
R5E
R4E
T2S
T3S
T4S
Qsc
Qal
QTt
Te
K
Jf
Tsp
B
B'
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
WATER WELL STANDARDS
SAN JOAQUIN COUNTY
AREAL GEOLOGY
SAN JOAQUIN COUNTY
SCALE OF MILES

LEGEND

QUATERNARY	RECENT - LATE PLEISTOCENE	Qal / Qb	**RECENT ALLUVIUM AND VICTOR FORMATION (Qal)** LENTICULAR SILT, SAND, GRAVEL, AND CLAY. MODERATELY PERMEABLE.
			FLOOD BASIN DEPOSITS (Qb) ORGANIC CLAY, SILT, AND FINE SAND LOW PERMEABILITY.
	PLIO-PLEISTOCENE	QTl	**LAGUNA FORMATION** SILT, SAND, GRAVEL, AND CLAY; INCLUDES ARROYO SECO GRAVEL. MEDIUM PERMEABILITY.
TERTIARY	MIO-PLIOCENE	Tm	**MEHRTEN FORMATION** VOLCANIC SANDSTONE, SILTSTONE, AND CONGLOMERATE; TUFF BRECCIA. MEDIUM TO HIGH PERMEABILITY.
	MIOCENE	Tvs	**VALLEY SPRINGS FORMATION** RHYOLITIC ASH, SAND, CONGLOMERATE, AND CLAY. LOW PERMEABILITY.

SYMBOLS

----?	CONTACT, DASHED WHERE APPROXIMATELY LOCATED, QUERIED WHERE UNCERTAIN.
I	LOGGED DRILL HOLES, WATER WELLS AND GAS WELLS.
-o-o-o-	APPROXIMATE BASE OF FRESH WATER, BELOW WHICH CHLORIDES GENERALLY EXCEED 300 PARTS PER MILLION.

ELEVATION IN FEET — U.S.G.S. DATUM

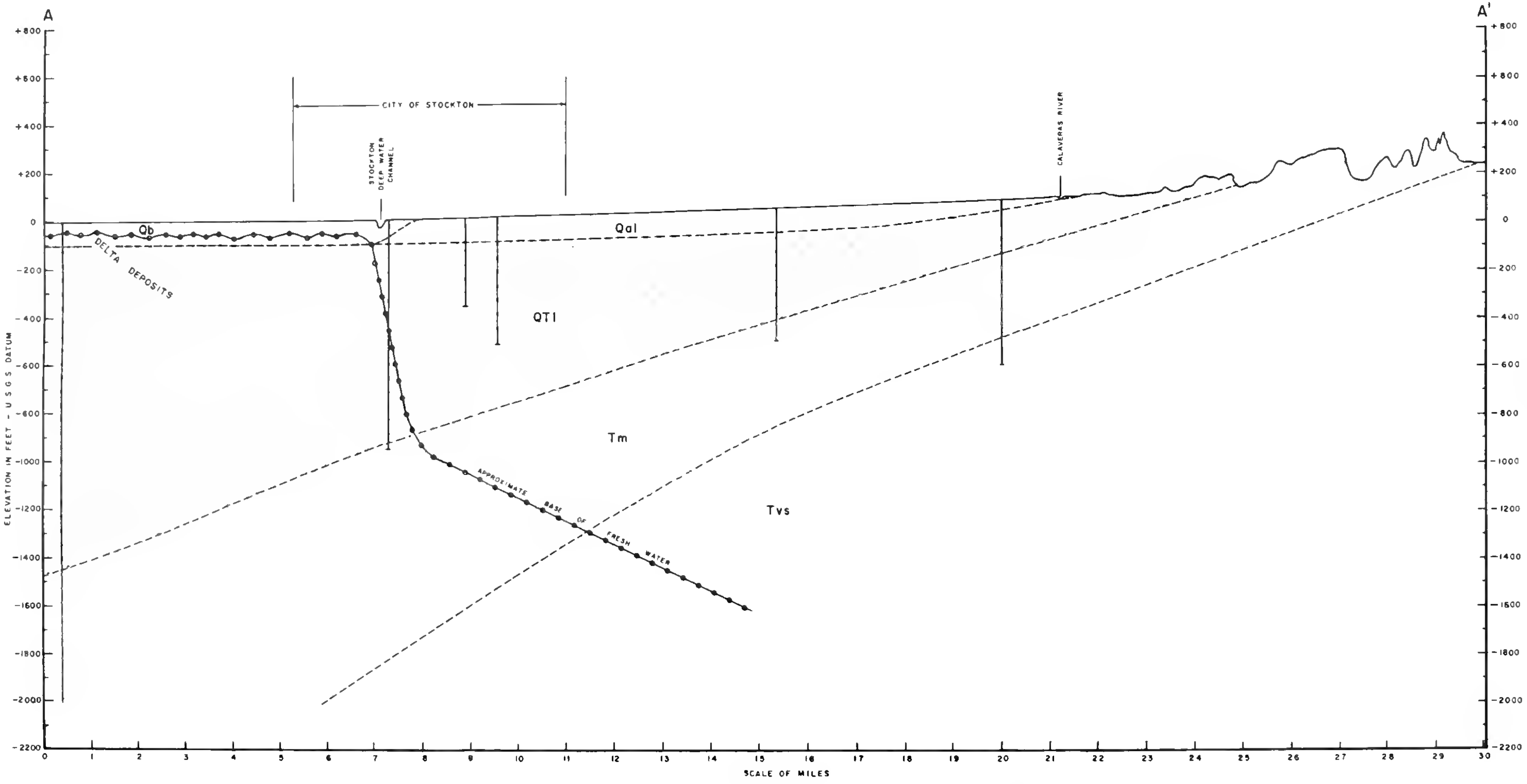
NOTES:

1. FOR LOCATION OF CROSS SECTIONS REFER TO PLATE 3 - AREAL GEOLOGY.
2. PERMEABILITY DESCRIPTIONS ARE AVERAGE FOR THE FORMATION; VARIATIONS FROM THE AVERAGE OCCUR LOCALLY.
3. GEOLOGY COMPILED AND MODIFIED FROM LITERATURE LISTED IN BIBLIOGRAPHY.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

GEOLOGIC SECTION
STOCKTON AND EASTERN AREAS



SECTION A - A'

LEGEND

QUATERNARY	RECENT - LATE PLEISTOCENE	Qal / Qb	RECENT ALLUVIUM AND VICTOR FORMATION (Qal) LENTICULAR SILT, SAND, GRAVEL, AND CLAY, MODERATELY PERMEABLE FLOOD BASIN DEPOSITS (Qb) ORGANIC CLAY, SILT, AND FINE SAND LOW PERMEABILITY
	PLIO-PLEISTOCENE	QTl	LAGUNA FORMATION SILT, SAND, GRAVEL, AND CLAY, INCLUDES ARROYO SECO GRAVEL MEDIUM PERMEABILITY
TERTIARY	MIO-PLIOCENE	Tm	MEHRTEN FORMATION VOLCANIC SANDSTONE, SILTSTONE, AND CONGLOMERATE, TUFF BRECCIA MEDIUM TO HIGH PERMEABILITY,
	MIOCENE	Tvs	VALLEY SPRINGS FORMATION RHYOLITIC ASH, SAND, CONGLOMERATE, AND CLAY LOW PERMEABILITY

SYMBOLS

- ----? CONTACT DASHED WHERE APPROXIMATELY LOCATED, QUERIED WHERE UNCERTAIN
- LOGGED DRILL HOLES, WATER WELLS AND GAS WELLS
- APPROXIMATE BASE OF FRESH WATER BELOW WHICH CHLORIDES GENERALLY EXCEED 300 PARTS PER MILLION

NOTES

1. FOR LOCATION OF CROSS SECTIONS REFER TO PLATE 3 - AREAL GEOLOGY
2. PERMEABILITY DESCRIPTIONS ARE AVERAGE FOR THE FORMATION, VARIATIONS FROM THE AVERAGE OCCUR LOCALLY
3. GEOLOGY COMPILED AND MODIFIED FROM LITERATURE LISTED IN BIBLIOGRAPHY

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS
SAN JOAQUIN COUNTY

GEOLOGIC SECTION
STOCKTON AND EASTERN AREAS

LEGEND

CHANNEL DEPOSITS
, COARSE SAND AND GRAVEL.
PERMEABILITY.

L FAN DEPOSITS (Qal)
OGENEOUS SEDIMENTS FROM CLAY TO GRAVEL.
ATE TO HIGH PERMEABILITY

BASIN DEPOSITS (Qb)
IIC CLAY, SILT, AND FINE SAND
PERMEABILITY

FORMATION
CONSOLIDATED GRAVEL, SAND AND CLAY
M PERMEABILITY. QTtc – CORCORAN CLAY.

LO GROUP
E, SANDSTONE, AND CONGLOMERATE.
TO MEDIUM PERMEABILITY.

EOUS
FFERENTIATED SANDSTONE AND SHALE.
RESH WATER-BEARING

SYMBOLS

, DASHED WHERE APPROXIMATELY LOCATED,
WHERE UNCERTAIN.

RILL HOLES, WATER WELLS AND GAS WELLS.

MATE BASE OF FRESH WATER, BELOW WHICH
S GENERALLY EXCEED 300 PARTS PER MILLION.

HOWING DIRECTION OF RELATIVE MOVEMENT.

OCATION OF CROSS SECTIONS REFER TO
3 – AREAL GEOLOGY.
ABILITY DESCRIPTIONS ARE AVERAGE FOR
ORMATION; VARIATIONS FROM THE AVERAGE
LOCALLY.
GY COMPILED AND MODIFIED FROM
ATURE LISTED IN BIBLIOGRAPHY.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
RTMENT OF WATER RESOURCES
DELTA BRANCH

VATER WELL STANDARDS:
SAN JOAQUIN COUNTY

EOLOGIC SECTION
TRACY AREA

LEGEND

CHANNEL DEPOSITS
, COARSE SAND AND GRAVEL.
PERMEABILITY.

L FAN DEPOSITS (Qal)
OGENEOUS SEDIMENTS FROM CLAY TO GRAVEL.
IATE TO HIGH PERMEABILITY.

BASIN DEPOSITS (Qb)
IC CLAY, SILT, AND FINE SAND
PERMEABILITY

FORMATION
CONSOLIDATED GRAVEL, SAND AND CLAY
M PERMEABILITY. QTtc – CORCORAN CLAY.

LO GROUP
, SANDSTONE, AND CONGLOMERATE.
TO MEDIUM PERMEABILITY.

EOUS
FFERENTIATED SANDSTONE AND SHALE.
RESH WATER-BEARING

SYMBOLS

, DASHED WHERE APPROXIMATELY LOCATED,
WHERE UNCERTAIN.

RILL HOLES, WATER WELLS AND GAS WELLS.

MATE BASE OF FRESH WATER, BELOW WHICH
S GENERALLY EXCEED 300 PARTS PER MILLION.

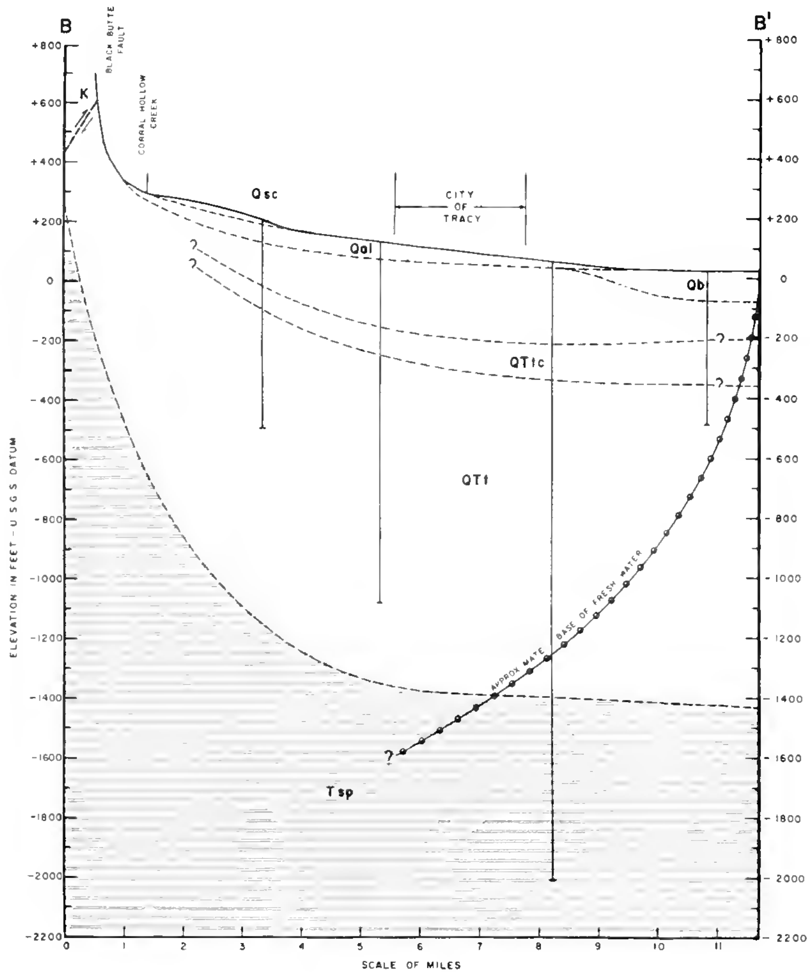
HOWING DIRECTION OF RELATIVE MOVEMENT.

OCATION OF CROSS SECTIONS REFER TO
3 – AREAL GEOLOGY.
ABILITY DESCRIPTIONS ARE AVERAGE FOR
ORMATION; VARIATIONS FROM THE AVERAGE
LOCALLY.
GY COMPILED AND MODIFIED FROM
ATURE LISTED IN BIBLIOGRAPHY.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
RTMENT OF WATER RESOURCES
DELTA BRANCH

VATER WELL STANDARDS:
SAN JOAQUIN COUNTY

EOLOGIC SECTION
TRACY AREA



SECTION B-B'

LEGEND

QUATERNARY	RECENT	Qsc	STREAM CHANNEL DEPOSITS LOOSE, COARSE SAND AND GRAVEL HIGH PERMEABILITY
	RECENT-LATE PLEISTOCENE	Qal / Qb	ALLUVIAL FAN DEPOSITS (Qal) HETEROGENEOUS SEDIMENTS FROM CLAY TO GRAVEL MODERATE TO HIGH PERMEABILITY FLOOD BASIN DEPOSITS (Qb) ORGANIC CLAY, SILT, AND FINE SAND LOW PERMEABILITY
TERTIARY	PLIO-PLEISTOCENE	QTt / QTtc	TULARE FORMATION SEMICONSOLIDATED GRAVEL, SAND AND CLAY MEDIUM PERMEABILITY QTtc – CORCORAN CLAY
	UPPER MIOCENE	Tsp	SAN PABLO GROUP SHALE, SANDSTONE, AND CONGLOMERATE LOW TO MEDIUM PERMEABILITY
CRETACEOUS	UPPER	K	CRETACEOUS UNDIFFERENTIATED SANDSTONE AND SHALE NONFRESH WATER-BEARING

SYMBOLS

- - - - ? CONTACT DASHED WHERE APPROXIMATELY LOCATED, QUERIED WHERE UNCERTAIN

LOGGED DRILL HOLES, WATER WELLS AND GAS WELLS

APPROXIMATE BASE OF FRESH WATER, BELOW WHICH CHLORIDES GENERALLY EXCEED 300 PARTS PER MILLION

FAULT SHOWING DIRECTION OF RELATIVE MOVEMENT

NOTES

1. FOR LOCATION OF CROSS SECTIONS REFER TO PLATE 3 – AREAL GEOLOGY
2. PERMEABILITY DESCRIPTIONS ARE AVERAGE FOR THE FORMATION, VARIATIONS FROM THE AVERAGE OCCUR LOCALLY
3. GEOLOGY COMPILED AND MODIFIED FROM LITERATURE LISTED IN BIBLIOGRAPHY

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THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS
SAN JOAQUIN COUNTY

GEOLOGIC SECTION
TRACY AREA

LEGEND

LINES OF EQUAL DEPTH TO WATER IN FEET

● WATER LEVEL MEASUREMENT WELLS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

GROUND WATER HYDROLOGY
LINES OF EQUAL DEPTH TO WATER IN WELLS
SPRING 1953

SCALE OF MILES

1 0 1 2 3 4

LEGEND

LINES OF EQUAL DEPTH TO WATER IN FEET

WATER LEVEL MEASUREMENT WELLS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

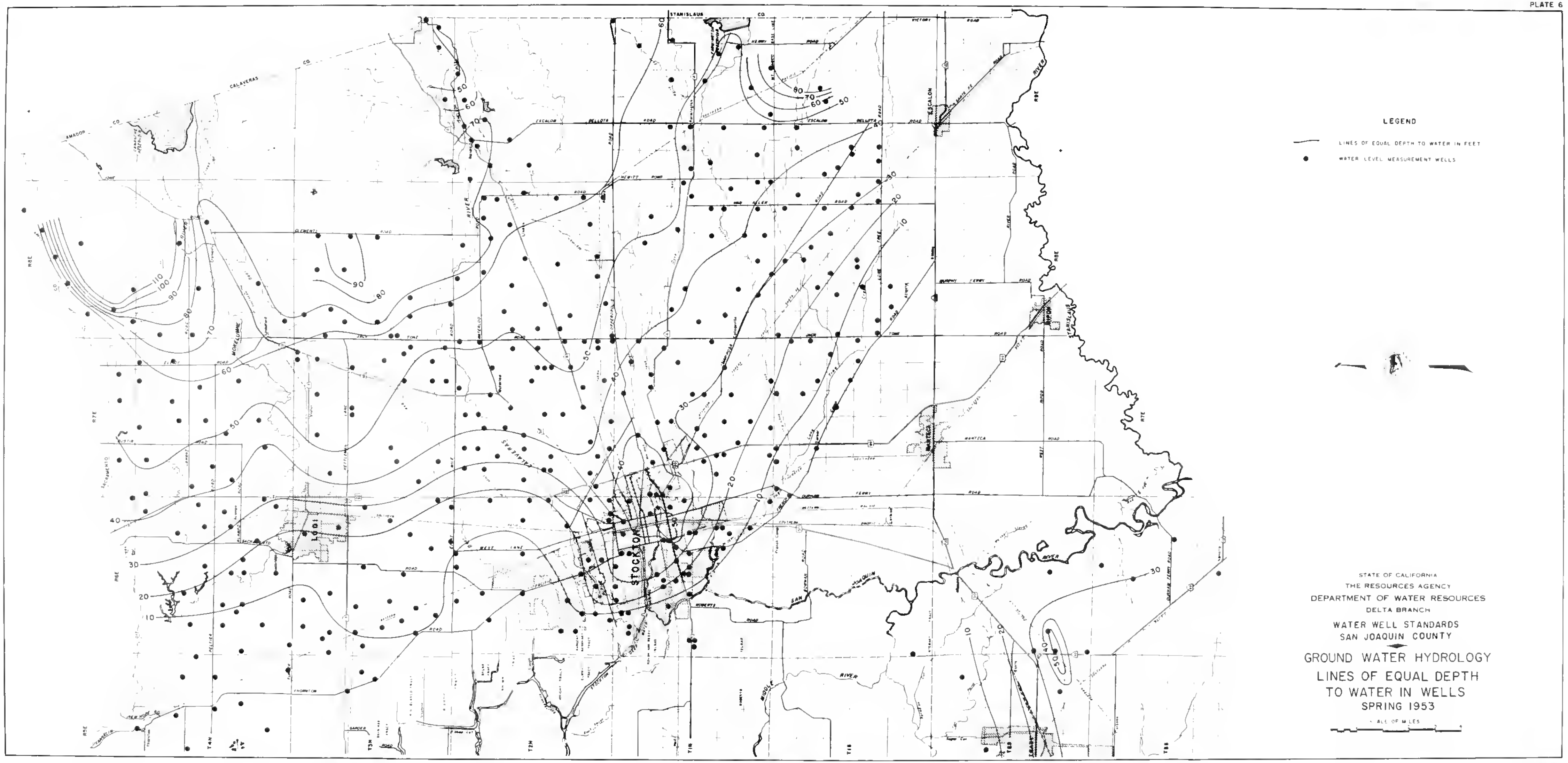
WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

GROUND WATER HYDROLOGY
LINES OF EQUAL DEPTH TO WATER IN WELLS
SPRING 1953

SCALE OF MILES

1 0 1 2 3 4

PLATE 6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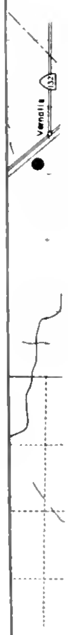
LINES OF EQUAL DEPTH TO WATER IN FEET
WATER LEVEL MEASUREMENT WELLS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
WATER WELL STANDARDS
SAN JOAQUIN COUNTY
GROUND WATER HYDROLOGY
LINES OF EQUAL DEPTH
TO WATER IN WELLS
SPRING 1953
STANISLAUS CO.
CALAVERAS CO.
AMADOR CO.
ESCALON
STOCKTON
LODI
MANTECA
RIPON
TRACY
MOKELUMNE
SAN JOAQUIN RIVER
STANISLAUS
CALAVERAS
MIDDLE RIVER
110
100
90
80
70
60
50
40
30
20
10

LEGEND

LINES OF EQUAL DEPTH TO WATER IN FEET

WATER LEVEL MEASUREMENT WELLS



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THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

GROUND WATER HYDROLOGY
LINES OF EQUAL DEPTH TO WATER IN WELLS
SPRING 1963

SCALE OF MILES
1 0 1 2 3 4

LEGEND

LINES OF EQUAL DEPTH TO WATER IN FEET

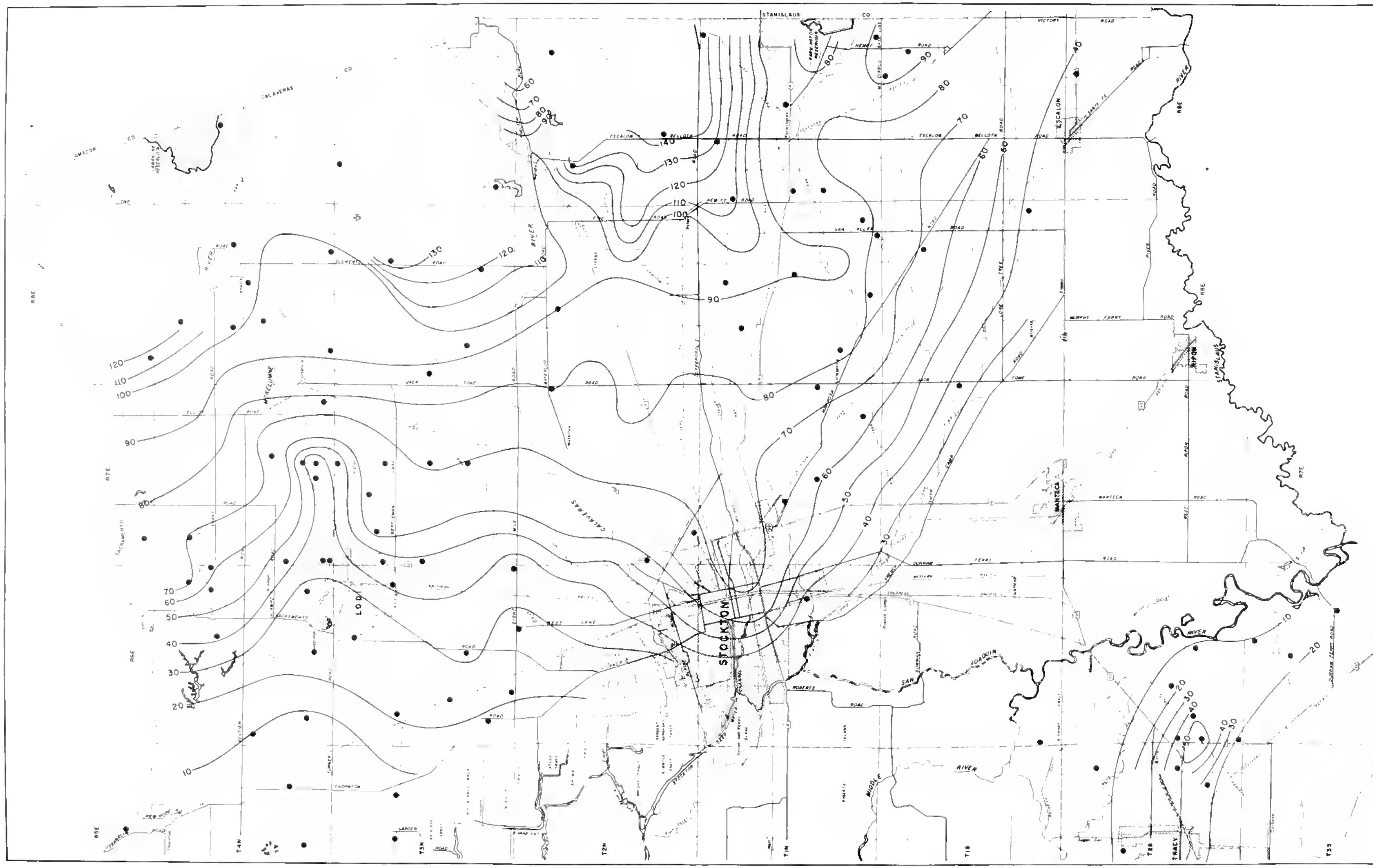
WATER LEVEL MEASUREMENT WELLS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

GROUND WATER HYDROLOGY
LINES OF EQUAL DEPTH TO WATER IN WELLS
SPRING 1963

SCALE OF MILES
1 0 1 2 3 4



LEGEND

LINES OF EQUAL DEPTH TO WATER IN FEET

WATER LEVEL MEASUREMENT WELLS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS
SAN JOAQUIN COUNTY

GROUND WATER HYDROLOGY
LINES OF EQUAL DEPTH
TO WATER IN WELLS
SPRING 1963

SCALE IN MILES

LEGEND

LINES OF EQUAL CHANGE OF DEPTH TO WATER IN FEET
– INDICATES LOWERING + INDICATES RISE

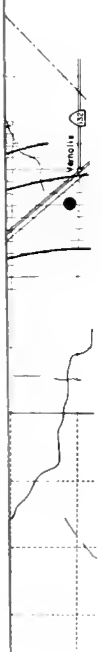
WATER LEVEL MEASUREMENT WELLS

INCREASES IN DEPTH TO WATER – 1953 TO 1963

- 0 ft TO – 10 ft
- –10 ft TO – 20 ft
- –20 ft TO – 30 ft
- –30 ft TO – 40 ft
- –40 ft TO – 50 ft
- –50 ft

DECREASES IN DEPTH TO WATER – 1953 TO 1963

- 0 ft TO + 10 ft
- +10 ft TO + 20 ft
- + 20 ft



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THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

GROUND WATER HYDROLOGY
LINES OF EQUAL CHANGE OF DEPTH TO WATER IN WELLS
SPRING 1953 TO SPRING 1963

SCALE OF MILES
1 0 1 2 3 4

LEGEND

LINES OF EQUAL CHANGE OF DEPTH TO WATER IN FEET
– INDICATES LOWERING + INDICATES RISE

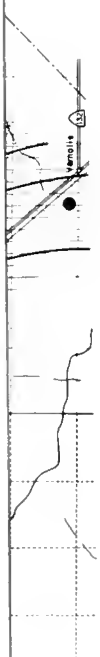
WATER LEVEL MEASUREMENT WELLS

INCREASES IN DEPTH TO WATER – 1953 TO 1963

- 0 ft TO – 10 ft
- – 10 ft TO – 20 ft
- – 20 ft TO – 30 ft
- – 30 ft TO – 40 ft
- – 40 ft TO – 50 ft
- – 50 ft

DECREASES IN DEPTH TO WATER – 1953 TO 1963

- 0 ft TO + 10 ft
- + 10 ft TO + 20 ft
- + 20 ft



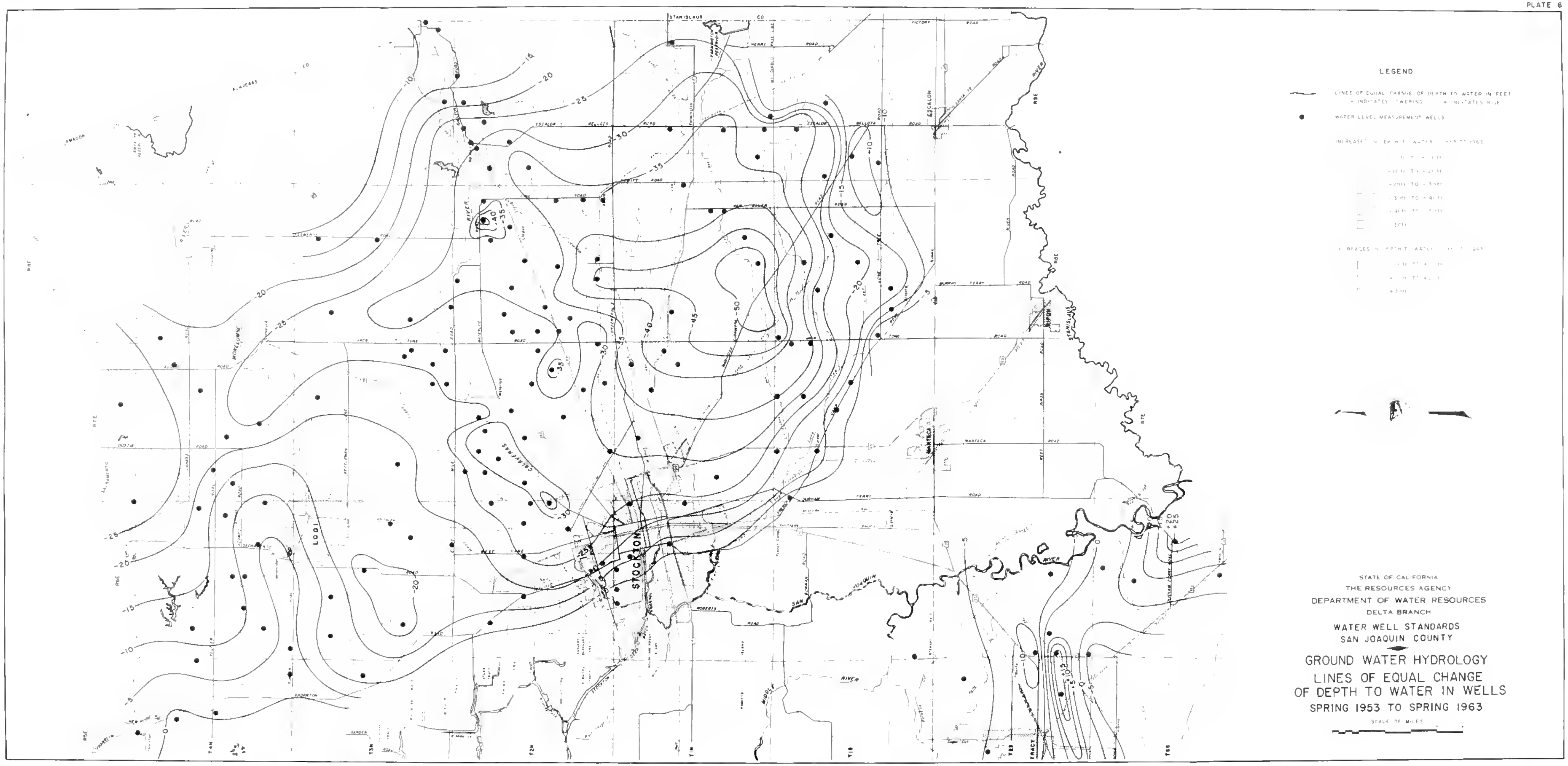
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

GROUND WATER HYDROLOGY
LINES OF EQUAL CHANGE OF DEPTH TO WATER IN WELLS
SPRING 1953 TO SPRING 1963

SCALE OF MILES
1 0 1 2 3 4

PLATE 8


LEGEND
LINES OF EQUAL CHANGE OF DEPTH TO WATER IN FEET
WATER LEVEL MEASUREMENT WELLS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
WATER WELL STANDARDS
SAN JOAQUIN COUNTY
GROUND WATER HYDROLOGY
LINES OF EQUAL CHANGE
OF DEPTH TO WATER IN WELLS
SPRING 1953 TO SPRING 1963
SCALE OF MILES
STOCKTON
LODI
MANTECA
TRACY
RIPON
ESCALON
STANISLAUS
CO
MOKELUMNE
CALAVERAS
SAN JOAQUIN
RIVER
MIDDLE

LEGEND

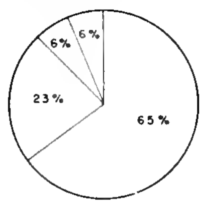
0 – 100 P.P.M.

100 – 350 P.P.M.

350 – 500 P.P.M.

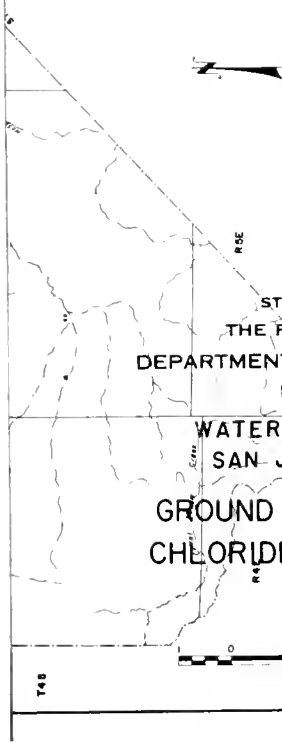
GREATER THAN 500 P.P.M.

DATA DENSITY FOR EACH
CONCENTRATION GROUP



TOTAL DATA – 699 ANALYSES

NOTE PARTS PER MILLION – (P.P.M.)



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

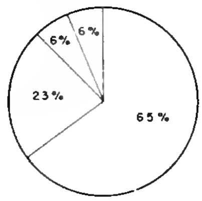
GROUND WATER QUALITY
CHLORIDE CONCENTRATION
1959

SCALE OF MILES
1 0 1 2 3 4 5 6

LEGEND

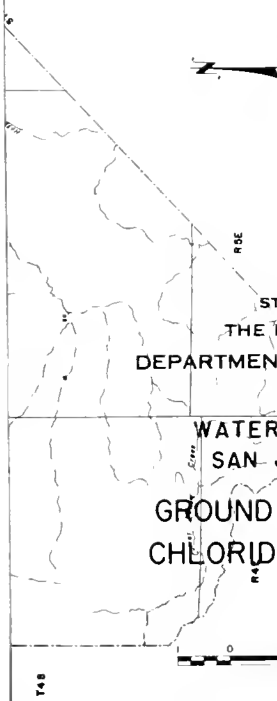
☐	0–100 P.P.M.
☐	100–350 P.P.M.
☐	350–500 P.P.M.
☐	GREATER THAN 500 P.P.M.

DATA DENSITY FOR EACH CONCENTRATION GROUP



TOTAL DATA – 699 ANALYSES

NOTE. PARTS PER MILLION – (P.P.M.)



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS: SAN JOAQUIN COUNTY

GROUND WATER QUALITY
CHLORIDE CONCENTRATION
1959

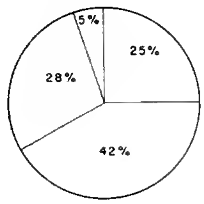
SCALE OF MILES
1 0 1 2 3 4 5 6


LEGEND
0-100 PPM
100-350 PPM
350-500 PPM
GREATER THAN 500 PPM
DATA DENSITY FOR EACH CONCENTRATION GROUP
6%
6%
23%
65%
TOTAL DATA - 699 ANALYSES
NOTE PARTS PER MILLION - (P.P.M.)
STOCKTON
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
WATER WELL STANDARDS
SAN JOAQUIN COUNTY
GROUND WATER QUALITY
CHLORIDE CONCENTRATION
1959
SCALE OF MILES

LEGEND

☐	0–100 P.P.M.	SOFT
☐	100–200 P.P.M.	MODERATELY HARD
☐	200–500 P.P.M.	HARD
☐	GREATER THAN 500 P.P.M.	HARD

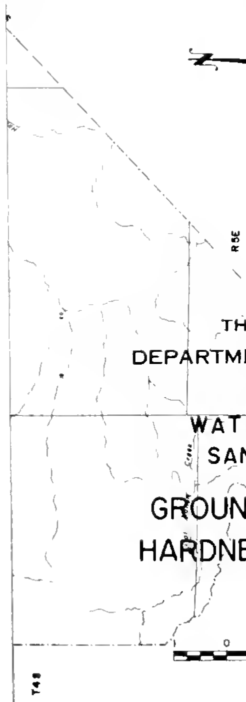
DATA DENSITY FOR EACH CONCENTRATION GROUP



TOTAL DATA – 448 ANALYSES

NOTES: HARDNESS EXPRESSED AS CALCIUM CARBONATE ($CaCO_3$) IN PARTS PER MILLION (P.P.M.)

GROUPING CORRESPONDS TO THE "HARDNESS CLASSIFICATION OF WATER"



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS: SAN JOAQUIN COUNTY

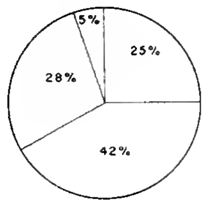
GROUND WATER QUALITY HARDNESS CONCENTRATION 1959

SCALE OF MILES
1 0 1 2 3 4 5 6

LEGEND

0–100 P.P.M.	SOFT
100–200 P.P.M.	MODERATELY HARD
200–500 P.P.M.	HARD
GREATER THAN 500 P.P.M.	HARD

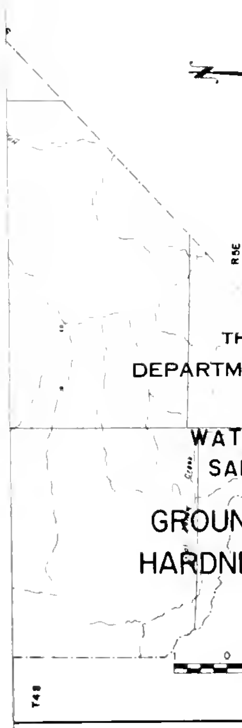
DATA DENSITY FOR EACH CONCENTRATION GROUP



TOTAL DATA - 448 ANALYSES

NOTES. HARDNESS EXPRESSED AS CALCIUM CARBONATE ($CaCO_3$) IN PARTS PER MILLION (P P M)

GROUPING CORRESPONDS TO THE "HARDNESS CLASSIFICATION OF WATER"



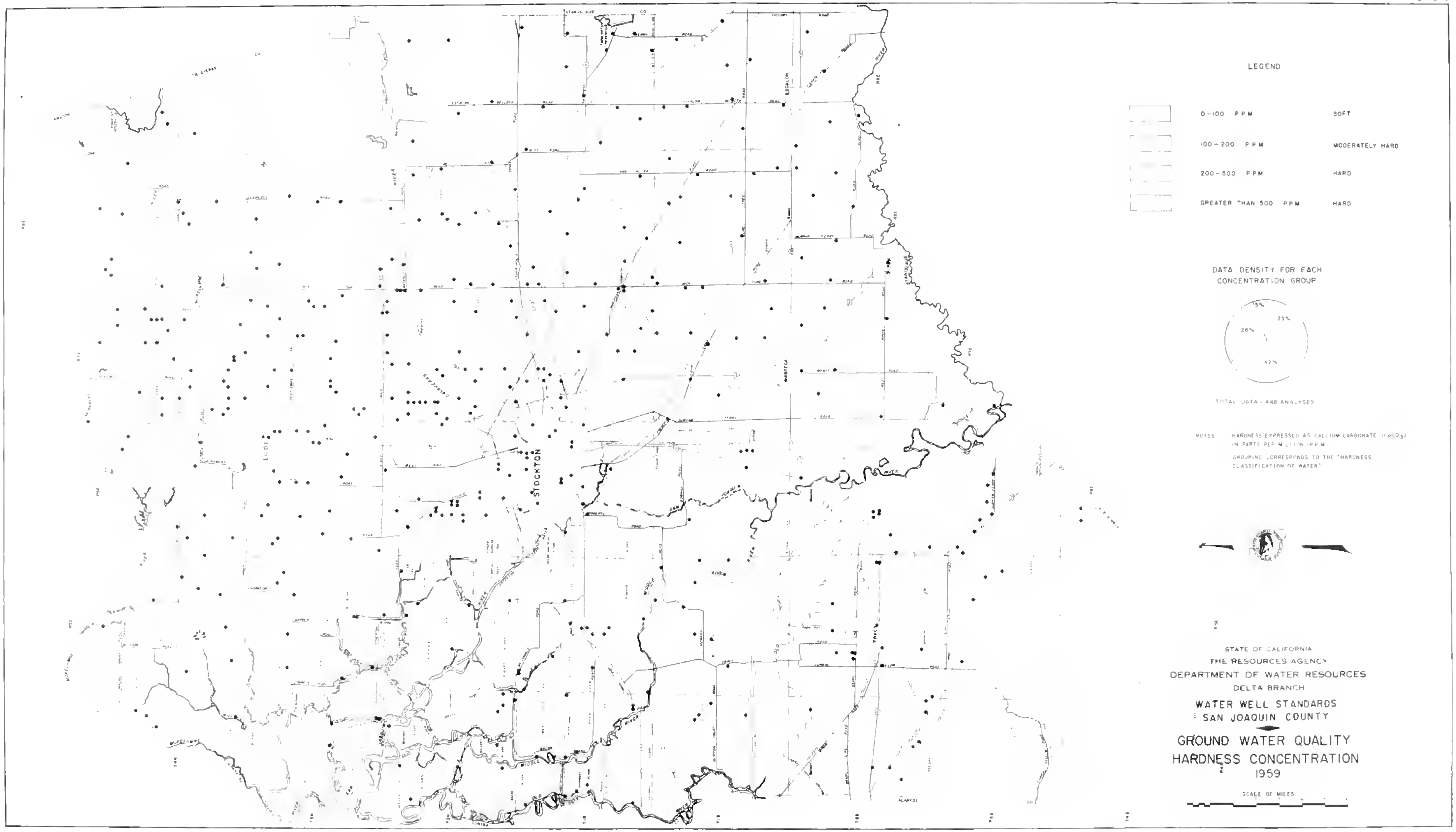
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS: SAN JOAQUIN COUNTY

GROUND WATER QUALITY HARDNESS CONCENTRATION 1959

SCALE OF MILES

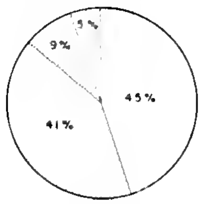
1 0 1 2 3 4 5 6


STOCKTON
LODI
ESCALON
MANTECA
TRACY
LEGEND
0-100 PPM SOFT
100-200 PPM MODERATELY HARD
200-500 PPM HARD
GREATER THAN 500 PPM HARD
DATA DENSITY FOR EACH CONCENTRATION GROUP
5%
25%
28%
42%
TOTAL DATA - 448 ANALYSES
NOTES
HARDNESS EXPRESSED AS CALCIUM CARBONATE ($CaCO_3$) IN PARTS PER MILLION (P.P.M.)
GROUPING CORRESPONDS TO THE "HARDNESS CLASSIFICATION OF WATER"
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
WATER WELL STANDARDS
SAN JOAQUIN COUNTY
GROUND WATER QUALITY
HARDNESS CONCENTRATION
1959
SCALE OF MILES

LEGEND

	0-0.5 P.P.M	CLASS 1
	0.5-2.0 P.P.M	CLASS 2
	2.0-5.0 P.P.M	CLASS 3
	GREATER THAN 5.0 P.P.M	CLASS 3

DATA DENSITY FOR EACH CONCENTRATION GROUP

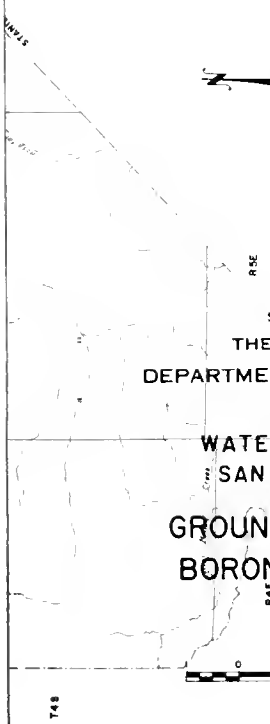


TOTAL DATA - 237 ANALYSES

NOTES

GROUPING CORRESPONDS TO THE "QUALITATIVE CLASSIFICATION OF IRRIGATION WATER"

PARTS PER MILLION - (P.P.M.)



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

GROUND WATER QUALITY
BORON CONCENTRATION
1959

SCALE OF MILES
0 1 2 3 4 5 6

LEGEND

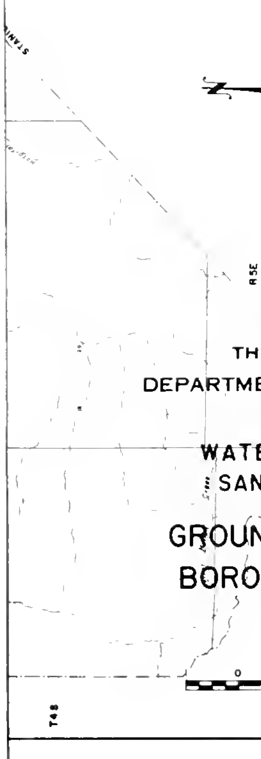
0–0.5 P.P.M.	CLASS 1	
0.5–2.0 P.P.M.	CLASS 2	
2.0–5.0 P.P.M.	CLASS 3	
GREATER THAN 5.0 P.P.M.	CLASS 3	

DATA DENSITY FOR EACH CONCENTRATION GROUP

TOTAL DATA–237 ANALYSES

NOTES: GROUPING CORRESPONDS TO THE "QUALITATIVE CLASSIFICATION OF IRRIGATION WATER"

PARTS PER MILLION – (P.P.M.)

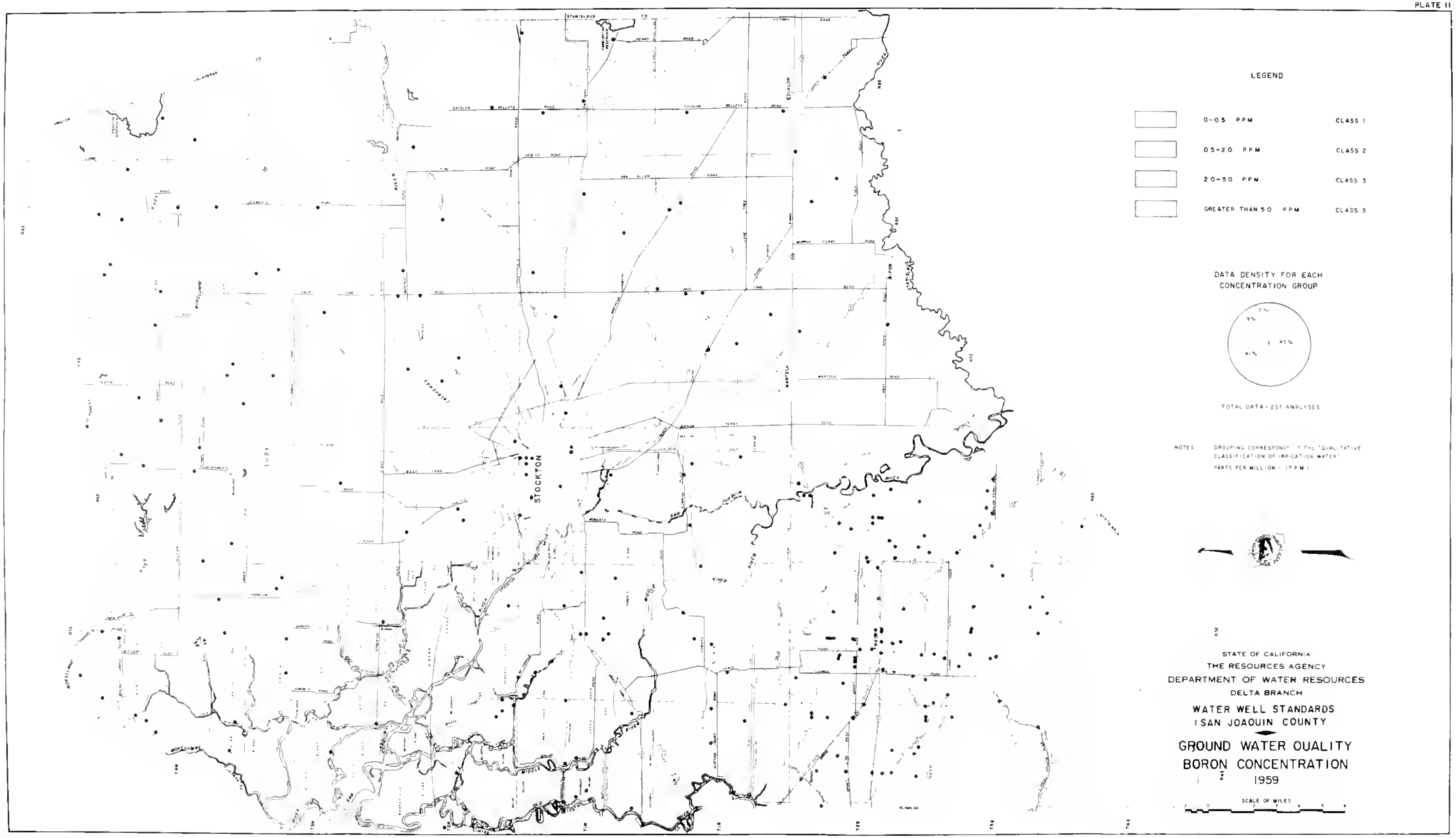


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WATER WELL STANDARDS:
SAN JOAQUIN COUNTY

GROUND WATER QUALITY BORON CONCENTRATION 1959

SCALE OF MILES
0 1 2 3 4 5 6


STOCKTON
LEGEND
0-0.5 PPM CLASS 1
0.5-2.0 PPM CLASS 2
2.0-5.0 PPM CLASS 3
GREATER THAN 5.0 PPM CLASS 3
DATA DENSITY FOR EACH CONCENTRATION GROUP
TOTAL DATA - 237 ANALYSES
NOTES
GROUPING CORRESPONDS TO THE "QUALITATIVE CLASSIFICATION OF IRRIGATION WATER"
PARTS PER MILLION - (P.P.M.)
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
WATER WELL STANDARDS
SAN JOAQUIN COUNTY
GROUND WATER QUALITY
BORON CONCENTRATION
1959
SCALE OF MILES